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ARCTIC NAVIGATION TASK ANALYSIS: DATABASE AND MODELLING

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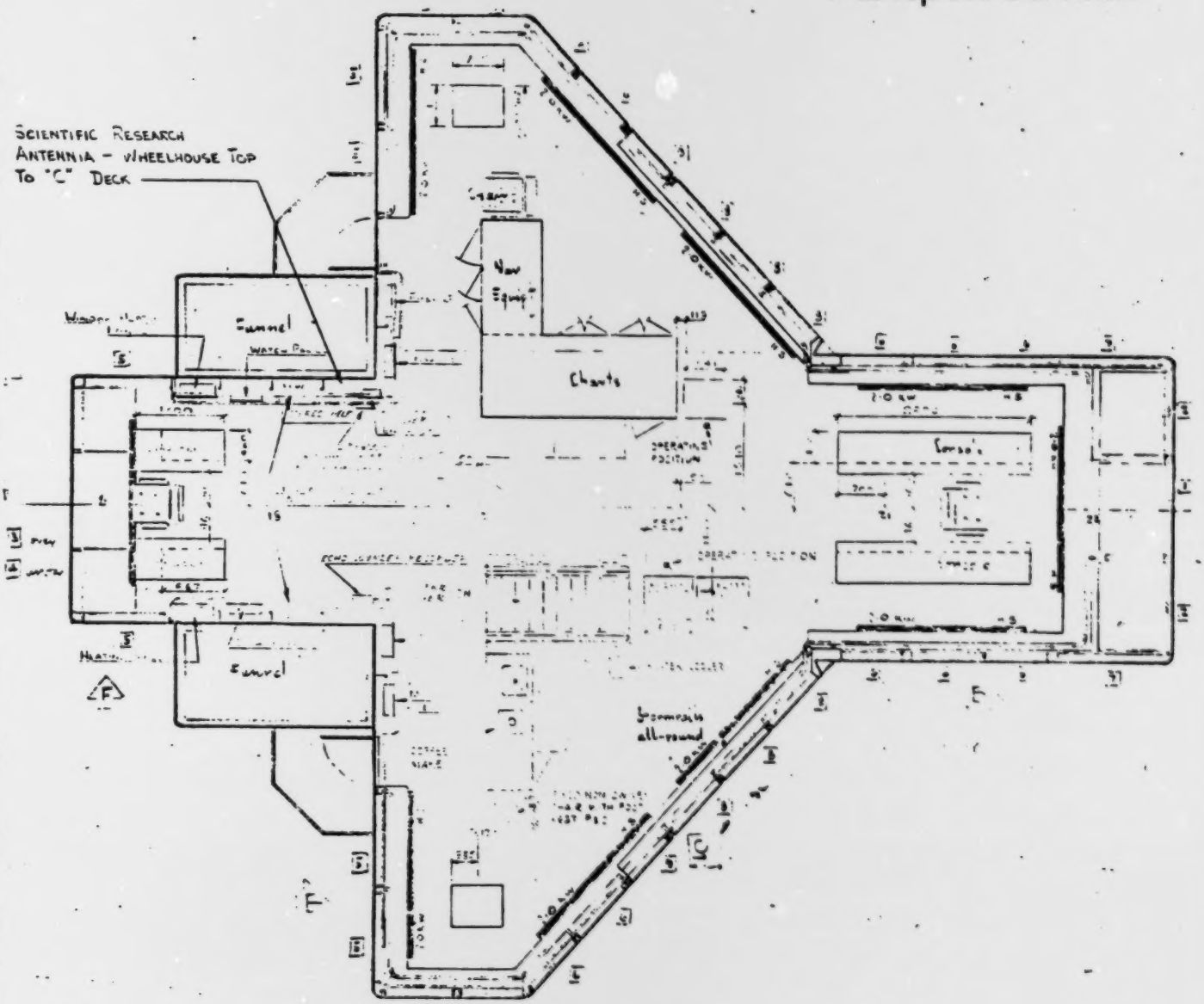

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By
D. C. Donderi and D. J. Ostry
Human Factors North, Inc. March 1986

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D.C. Donderi and D.J. Ostry

Human Factors North Inc.

Toronto Ontario

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PROJECT TEAM

The project team for Human Factors North was composed of:

D.C. Donderi, principal consultant

D.J. Ostry, principal consultant

M. Dansereau, technical associate

R. Grimes, research assistant

S. Rappaport, research assistant

B. Laberge, research assistant

M. Edelman, research assistant

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17. Abstract

The aim of this project was to establish a database of operator activities, communications and movements that occur on ships bridges in Arctic navigation and to apply stochastic modeling techniques to the data to reveal the structure and dependencies among these events. A flexible, easy-to-use database was developed by coding the shipboard activities to conform with the file structure conventions of the SPSS-X language. This provides access to the full range of data management and statistical packages available in SPSS-X without the associated costs of developing a special purpose language. In the report, the organization of the database and access to it are described. Figures, tables and summary statistics are presented which describe the frequency of occurrence of various events on each of the ships in the database and their distributional characteristics. The stochastic structures of the activities, communications, and movements of the officers are assessed. As is the case in other complex systems such as jet aircraft and nuclear power plants, activity durations for radar use and communications are exponentially distributed. Specific recommendations regarding the placement of radars and communications equipment, chart table design and operator training are offered on the basis of the findings.

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17. Résumé

Ce rapport concerne l'établissement d'une base de données sur les activités, communications et mouvements du personnel en poste sur les passerelles de navigation des navires évoluant dans l'Arctique. Cette base de données devait servir à mettre en lumière l'organisation et les interrelations de ces événements par le biais d'une modélisation de type stochastique. L'étude a débouché sur une base de données souple et facile à exploiter du fait que le codage des activités recensées a été conformé aux règles d'organisation des fichiers propres au langage de simulation SPSS-X utilisé. De cette façon, on peut traiter les données acquises par toute la gamme des programmes de gestion des données et de traitement statistique du SPSS-X sans avoir à élaborer un langage spécialisé. Le rapport décrit l'organisation de la base de données et les méthodes d'accès utilisables. Il présente aussi des figures, des tables, et des tableaux statistiques qui indiquent la fréquence et les caractéristiques de distribution des divers événements contrôlés à bord des navires figurant dans la base de données. Enfin, il examine, en vue de la caractériser, la structure stochastique des activités, communications et mouvements des officiers. Ainsi, met-il en évidence la distribution exponentielle des durées d'utilisation du radar et des communications, soit le même type de distribution que celle constatée dans l'exploitation d'autres systèmes complexes comme les avions à réaction et les centrales nucléaires. En conclusion, le rapport apporte des suggestions concernant l'emplacement souhaitable des radars et des appareils de communication sur la passerelle, la conception des tables à cartes et la formation du personnel.

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SUMMARY

A database was established containing records of activities and movements of bridge crew recorded aboard the M.V. Arctic, M.S. Thuleland, and M.V. Canmar Kigoriak. The records were obtained during navigation in ice in the eastern Arctic and in the Beaufort Sea from June 1983 to October 1984. They were stored both as ASCII character files and as files which can be read by the SPSS^X database management and statistical analysis system. The files are on 1600 bpi, 9-track magnetic tape formatted for use on a DEC operating system.

Analysis was undertaken to establish the sequential pattern of positions and activities of masters and watch officers. The transitions between positions and sequences were analyzed separately to determine whether each position or activity was 1) independent of all those which preceded, 2) depended on the previous position or activity, or 3) depended on a sequence of two or more previous positions or activities. Also, the frequencies with which different positions were occupied and different activities were undertaken were calculated as a function of the type of ice cover and the presence of daylight or darkness for officers aboard all three ships.

Activity sequences for two masters were highly structured. The occurrence of each activity was predictable from the sequence of two or more preceding activities. Masters' activity sequences were characterized by a recurrence of visual observation (for example, the sequence visual observation--communication--visual observation, or the sequence visual observation--radar observation--visual observation). For most of the watch officers, each event was predictable from the immediately preceding event. Characteristic sequences were vision--radar observation, or vision--communication. Visual observation was a common antecedent or consequence of most other activities. For two watch officers, there was no discernable pattern to successive positions or activities.

Although activity sequences were predictable, activity durations were not. An analysis of the duration of radar and communications activities indicated that their distribution was exponential. This means that the individual event has the same probability of termination at any point during its occurrence, and that the termination of a particular activity is a random process.

The frequency of individual activities differed across officers and environments. Masters spent more time making visual observations; watchkeeping officers spent more time in navigating activities and less in visual observation. Radar use increased, and direct visual observation decreased, at night. More time was spent at visual observation in ice cover than in open or bergy water. Radar use also increased in ice.

The main conclusions are that piloting stations must have radar and communications equipment; that visual observation must be possible from the chart table, and that procedures should be modified to reduce the time spent in less essential navigation activities.

RESUME

Des données concernant les activités et les déplacements de l'équipage de pont, ont été relevées à bord des M.V. Arctic, M.S. Thuleland et M.V. Canmar Kigoriak. Ces informations ont été obtenues au cours de la navigation glaciaire dans l'ocean arctique de l'est et dans la mer de Beaufort entre juin 1983 et octobre 1984.

L'analyse avait pour but d'établir un tableau séquentiel des positions et des activités des maîtres et des officiers de garde. Les transitions entre les positions et les séquences furent analysées séparément, afin de déterminer si chaque position ou activité s'avérait 1) indépendante de celles l'ayant précédé, 2) dépendante de la position ou de l'activité précédente, ou 3) dépendante d'une séquence (2 ou plus) de positions ou d'activités. La fréquence avec laquelle différentes positions étaient occupées et différentes activités entreprises a été également calculée; ceci en fonction du genre de surface de glace, et en fonction du contexte lumineux présent (lumière du jour, pénombre) pour les officiers à bord des trois navires.

Les séquences d'activité pour deux des maîtres s'avérèrent très structurées. L'apparition de chaque activité pouvait être prédite à partir de la séquence (de deux ou plus) des activités précédentes. Celles-ci possédaient comme caractéristique la répétition de l'observation visuelle (par example: la séquence observation visuelle - communication - observation visuelle). En ce qui concerne les officiers de garde, chaque évènement pouvait être prédit par la précédent, ceci pour la majorité d'entre eux. L'observation visuelle était un antécédent ou une conséquence communs à la plupart des autre activités. Il ne fut pas possible de discerner de régularités dans les positions et activités successives de deux des officiers de garde.

Bien qu'il ait été possible de prédire les séquences d'activités, il n'en fut pas de même pour leurs durées. Une analyse de la durée des activités ayant trait au radar et aux communications indiqua une distribution exponentielle. Cette caractéristique signifie que 1) chaque évènement a la même probabilité de se terminer à tout moment, et que 2) la terminaison d'une activité donnée est déterminée par le hasard.

La fréquence des activités individuelles était différente selon les officiers et les environments. Les maîtres passaient plus de temps à faire des observations visuelles, alors que les officiers de gard s'occupaient plus de la navigation. Pendant la nuit, l'utilisation du radar augmentait alors que l'observation visuelle directe se faisait moins fréquente. Plus de temps était alloué à l'observation visuelle dans un couvert de glace par rapport aux eaux libres ou en présence d'icebergs. L'utilisation du radar augmentait également dans les glaces.

Les conclusions principales sont: les positions de garde doivent être à proximité de l'équipement de radar et de communication, l'observation visuelle doit être possible à partir de la table de navigation et finalement, les procédures doivent être modifiées afin de réduire le temps consacré aux activités de navigation moins essentielles.

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ARCTIC NAVIGATION TASK ANALYSIS: DATABASE AND MODELING

D.C. Donderi and D.J. Ostry
Human Factors North Inc.

1. INTRODUCTION

1.1 Background

During the course of a contract to study research priorities for an Arctic shiphandling simulator, Human Factors North (formerly Man-Machine Systems Consultants Inc.) carried out task analyses aboard the M.V. Arctic, a 28000 dwt icebreaking ore carrier owned by Canarctic Shipping Ltd. Task analysis data were obtained by recording the position and activity of up to six different bridge personnel once every fifteen seconds. The analyses took place in Davis Strait and Lancaster Sound, in July and October of 1983. The results are reported in Donderi and Ostry (1985).

In addition to the information relevant to simulation, the task analysis yielded other information. Since there was a position and activity sample every fifteen seconds, it was possible to reconstruct the sequences of movement between one bridge position and another, as well as the sequences of activities. These sequences will be useful in bridge design in order to establish equipment placement which takes account of patterns of successive activities. They will be useful for training, because differences in activity and movement sequences between experienced and inexperienced bridge personnel can be used as a basis for planning instruction in bridge procedures. They will be useful in studies of Arctic navigability, because differences in activity and movement sequences and timing can be used to assess the workload of bridge crew members, which is related to operating safety. And these data will be useful in evaluating the validity of simulated Arctic navigation, because activity and position frequencies and sequences observed in a simulation can be compared to the data collected aboard ship to see if the sequences in the simulated environment are like those in the real environment.

1.2 Sequential Dependence

Transitions between successive activities or positions (called "states" in statistical language) can be evaluated statistically to determine whether the sequence of states occurs at random, whether the sequence of states is determined by the immediately preceding state, or whether the sequences of states is determined by two or more preceding states. A succession of states in which the probability of moving from one state to the next depends on only the probability of each state is a random sequence, and it is called a zero-order Markov process. A succession of states in which the probability of moving from one state to the next depends on the immediately preceding state is called a first-order Markov process. A succession of states in

which the probability of moving from one state to the other depends on the two preceding states is called a second-order Markov process. Successions of states in which the probability of moving from one state to the next depends on a sequence longer than the preceding two states are called higher-order Markov processes (Feller, 1973).

The application of these principles will be clearer if an example is presented in maritime language. If the probability that the officer of the watch will move to the main console at the next sampling interval is .10 regardless of where he now is on the bridge, his activity is an example of a zero-order Markov process. If the probability of his moving to the main console is .10 if he is now at the port bridge wing but is .20 if he is now at the chart table, his activity is an example of a first-order Markov process. And if the probability of his moving to the main console is .10 when he is now at the port bridge wing but has just been at the starboard radar, while it is .25 when he is now at the port bridge wing but has just been at the chart table, he is an example of a second-order Markov process.

As can be seen from these examples, the order of the Markov process which describes the sequence of states is an indicator of the amount of order in the sequence of activities or positions. An officer whose behavior is predictable from his two or three previous positions or activities shows more regularity of behavior than an officer whose present activity is predictable only from his immediately preceding activity, and considerably more regularity than an officer whose present activity is totally unpredictable from the sequence of his earlier activities.

Statistical techniques have been developed to compare an existing sequence of states with the sequence predicted from a Markov process of any order. They are reviewed in Dansereau (1974). These techniques were used to estimate the goodness-of-fit of the activity and position sequences obtained in the task analysis data to the sequences expected from zero, first, or higher-order Markov processes. The actual sequences of positions and activities, as well as the proportion to sampling intervals on which each position and activity was recorded, also provide information about the work carried out by different bridge crew members under different conditions.

Tranportation Development Centre was interested in an investigation of the sequential aspects of the task analysis data and in other broader applications of the data. What is the pattern of Markov order for positions and activities? Is it the same on all bridges? Does the pattern differ from one officer to another? What statistical sequences characterize individual activities like visual observation and communicationion?

These are important questions because they bear on the efficiency of bridge operations. Different bridge layouts or bridge procedures, differences in workload, manning levels, or even different degrees of training and experience may influence the sequences of movement and communication. Systematic dependencies in movements or communications will lead to the generation of higher-order Markov chains. In effect, the probabilistic dependencies among the movements and communications

of the officers on the ship's bridge may provide a quantitative measure which can be used to assess the consequences of different bridge layouts and procedures, to evaluate operator performance in different workload conditions (e.g., different ice types, concentrations, and visibility) and to examine performance changes as a function of manning.

1.3 Data Base

In addition to the data gathered aboard the M.V. Arctic on two voyages in 1983, data were obtained in September and October 1984 aboard the M.S. Thuleland in the eastern Arctic and aboard the M.V. Canmar Kigoriak in the Beaufort Sea. These data were obtained while completing a contract to study aspects of Arctic navigability and bridge design for TDC.

A variety of navigation situations were sampled. These include navigating in open water, bergy water, new ice, first year ice, old ice and docking. The recordings were made both in daylight and night conditions, in good visibility and in fog. Differences in bridge design, equipment, procedures and the manning of the ships included in this data base provide a range of situations for modelling.

Each sample consists of notations which indicate the wheelhouse position occupied by each of the people observed and which describe the activities in which each person was engaged when the sample was taken. Details of the data collection procedure are included in Donderi and Ostry (1985).

Only one other similar database has been reported in the technical literature. Miller and Hansford (1983) report a comprehensive study of bridge crew performance from 50 ships operating in a variety of open-water and harbour conditions. However, the database assembled under the present contract is unique in that it was obtained during navigation in ice.

2. METHOD

2.1 Data

2.1.1 Observation Techniques

Equipment. Observers were equipped with a clipboard, large spiral-bound notebooks, pen or pencil, and wristwatch with a sweep second hand. At night, observers also carried portable battery-operated lights attached to the clipboard. The lights were red-filtered to reduce overall light output and to prevent loss of dark adaptation.

Observers. Observers were the principal investigators, or their technical associates. Five observers collected the data. The observers were present in an inconspicuous location on the bridge during the observations. On the conventional bridges of the two bulk carriers M.V. Arctic and M.S. Thuleland, the observer customarily stood to one side of the bridge, near the after bulkhead, and in a position where the view forward included the officers on duty across the entire width of the bridge. On the icebreaking supply boat M.V. Canmar Kigoriak, the observer's position varied according to the activity. When the ship was being operated from the main console, it was forward, directly behind or alongside the main operator's position. When the ship was being operated from a wing console, the position was to either side, near the active console.

Sampling Interval. A record was made every fifteen seconds. The sampling interval was determined by reference to the sweep second hand of a wristwatch. Thus the data are a discontinuous record of the continuous flow of activity and change of position in the wheelhouse. The single position occupied by each operator at the sampling moment was recorded. Up to three activities of each operator which had been carried out during the sampling interval were also recorded.

Episodes. Recording was organized into separate units called episodes, which consisted of successive sampling intervals. Episodes ranged from twenty minutes to three hours in length. Each episode was recorded continuously from beginning to end by the same observer. Each episode was characterized by a set of data describing the fixed environmental and personnel conditions under which the episode was recorded.

2.1.2 Variables Recorded

Number of operators. The positions and activities from one to six operators were recorded for each sampling interval. The minimum number was one, if only the Officer of the Watch (OW) or the Master was present. Data were recorded for other officers present (as was frequently the case in ice-covered or bergy water). In addition, ice observer's and helmsman's positions and activities were recorded when the situation warranted.

Position codes. The bridge of each ship was divided into imaginary zones. The numbered zones of necessity differed from ship to ship, because the shape and layout of the bridges differed. The bridge plans for each ship are presented in Appendix A. The number of the zone in which the operator was standing was recorded at the sampling moment. If the operator was in motion at the sampling moment, the symbol T (for transit) was recorded. If the operator (who had previously been observed) was not on the bridge, the symbol OFF was recorded.

Activity codes. The following activities were coded and recorded for each person under observation: visual observation forward, abeam, or aft, binocular use, radar use, use of night vision aids, voice communication (operations only), phone communication, intercom communication, P.A. or loud-hailer communication, radio communication, chart table operations, weather facsimile use, console manipulations, including power setting and course changes, and non-activity.

Fixed conditions. For each episode, the following data were recorded: the date, GMT, latitude, longitude, local time, course, speed, heading, wind speed and direction, sea state, ice type, ice cover, visibility, and the identification codes for the operators under observation. During observations aboard the icebreaking supply boat which changed course frequently, sample-by-sample changes in course heading were also recorded.

Comments. Notes regarding manoeuvres, environmental conditions, or operator activities which could not be coded within the sampling interval system were written directly into the notebooks. These comments, which ranged from two or three-word notes to paragraphs, were included in the datasets into which the original data was coded.

2.1.3 Data Transfer to Computer Files

The data recorded in each observer's notebook were transcribed onto standard coding forms. Each form represented one computer record. The transcription was carried out by a research assistant in cooperation with the observer who had recorded the data. The coder checked the records with the observer as the notebook was being transcribed. Once the transcription was complete, the transcibed records were verified against the notebook by the coder.

Each coding form was entered into a computer file. Then, once the coding for an entire notebook had been completed, the computer file was verified against the coding forms in a separate operation. For the files corresponding to one of the ships, the entry and the verification were carried out by two different people. For files corresponding to the other two ships, the coding and verification were carried out by the same person.

2.2 File Structure

Two types of permanent records were generated from the original data recorded in notebooks. One type of record was a character file which duplicated the original data as recorded. The existence of the

character files allows access to the raw data including all of the comments recorded during the observation periods. The comment records, being literal records of varying length, were not suitable for statistical data reduction using the SPSS^X system. Existence of the characgter files also allows complete re-analysis of the data using different assumptions and techniques by other researchers.

The second type of permanent record was an SPSS^X system file which contained, in addition to the original character variables, numerically recoded versions of the character variables which are more easily manipulated using SPSS^X data analysis programs. The SPSS^X file did not contain the comments recorded in the character file.

2.2.1 Character Files

These files contain records of all of the variables originally recorded. A separate file was generated for each ship. Each file consists of 80-column records.

The basic structure of the file is a series of episodes. As mentioned earlier, each episode is a succession of samples recorded by one observer over a continuous period ranging from about twenty minutes to about three hours. Five record types were used to encode this data. The variables describing the fixed conditions within each episode were recorded on one type 1 and one type 2 record which were always the first two records in the episode. The position and activity variables for the first three operators at each sampling interval were recorded on record type 3. The position and activity variables for operators four through six at each sampling interval (if more than three operators were observed) were recorded on record type 4. Comments were recorded on record type 5 wherever they occurred throughout the episode.

To review: an episode within a file begins with a single type 1 record followed by a single type 2 record. The variables which described the fixed conditions of the episode were recorded on record types 1 and 2. An episode with four to six operators would then continue with a series of alternating type 3 and type 4 records. There were as many pairs of type 3 and type 4 records as there were sampling intervals in the record. Comments, written out on type 5 records, were inserted into the episode in the appropriate chronological position.

An episode with three or fewer operators consisted of a single type 1 and a single type 2 record, followed by as many type 3 records as there were sampling intervals. Type 5 records recorded comments in the appropriate chronological position.

A table describing the format for each record type is found in Appendix B. The table gives the name of each variable, a description of its content and the range of its values, and the columns in which it was entered.

2.2.2 SPSS^X System Files

SPSS^X system files are numerical recodings of the character files described in Section 2.2.1. One system file was generated for the data from each ship.

SPSS^X. SPSS^X is a general purpose file management and data analysis program. It is available for many computer systems, including those used by IBM and the Digital Equipment Corporation. It was chosen for this project specifically because of its ability to process data from "nested file" structures.

A "nested file" structure is one in which data on some records is related to data on other records in the file. For the task analysis data, within each episode, the variables recorded on record types 1 and 2 are related to all of the sampling interval variables recorded on record types 3 and 4.

The basic unit for statistical analysis in SPSS^X is a "case". A "case" in this database consists of a single sampling interval (the data recorded on record types 3 and 4) along with the related variables (recorded on record types 1 and 2). SPSS^X file generation instructions allow the construction of a complete "case" file for each episode from the "nested" character files described in the previous section.

Transformations. Each of the single position and three activity variables recorded for each operator was originally recorded in character form. These variables were recoded into numerical form to facilitate subsequent processing. The transformed codes are given in Appendix B.

File Documentation. The format of each SPSS^X system file is documented in Appendix B. This Appendix includes a listing of the variables, a summary of the possible values, a brief description of each variable, and the format listing for the file.

2.2.3 File Names and Data Tape

Six files have been presented on magnetic tape as a physical appendix to this report. There is a character file and an SPSS^X system file for the data from each ship. Table 1 lists the names of the file for each ship.

Table 1 File Names

Ship	File Names	
	Character	System
M.V. Arctic	#MCH.ADATA	#MCH.ASYST
M.S. Thuleland	#MCH.TDATA	#MCH.TSYST
M.V. Canmar Kigoriak	#MCH.KDATA	#MCH.KSYST

The data tape is a 9-track, 1600 BPI tape which has been labeled for a DEC system operating on RSX-11M.

2.3 Analytical Programs

This section outlines five programs which were written to carry out analysis of the data. Four of the programs are written in the command language of SPSS^X. They provide various ways of partitioning the data set. The fifth is a FORTRAN program which tests the order of the Markov chains.

2.3.1 SPSS^X Programming Features

A useful feature of the SPSS^X language is a statement, SELECT IF, which enables a file to be screened for cases which have a specific value or values on one or more numerical or character string variables. Any of the SPSS^X programs written for these analyses can be applied to a selected subset of all the data cases which is specified by an appropriately written SELECT IF statement.

In addition, SPSS^X allows the user to easily prepare frequency counts and cross-tabulations of specific sets of variables. All of these features will be useful to subsequent users of this database.

2.3.2 Position Sequence Analysis

The purpose of the program is to list the successive bridge positions occupied by a particular operator over a series of successive cases (sampling intervals). Operator selection is accomplished by changing the value of one constant in the program listing. The program generates three sets of outputs. The first is a transition matrix listing the frequency of transitions between all pairs of positions occupied on successive sampling intervals. All intervals and transitions are given equal weight so that the analysis records and sums even the transitions which leave position unchanged. The second output is a listing of the sequence of positions occupied, and the duration (in sampling interval units) that each position was

occupied. This output is used by the FORTRAN program to test the position sequence for markov chain order. The third output is a transition matrix which records the transitions between successive positions, rather than successive sampling intervals. In this matrix, only transitions between distinct positions are counted, and so the main diagonal (which records transitions between a position and itself) is empty. The off-diagonal cells count the number of times each pair of positions occurred in sequence. The program listing and sample output is presented in Appendix C.

2.3.3 Multiple Activity Analysis

The data files record up to three activities per sampling interval for each operator. Measurement of the relative frequencies of occurrence of different activities requires that all three activities be given equal weight. This program is built around a programming function in SPSS^{X} which makes it possible to produce frequency counts and cross-tabulations from a set of equivalent variables like the three activity variables for each operator. The output from this program is a listing of the activity frequencies for up to nine different operators. The program listing and a sample output are presented in Appendix C.

2.3.4 Single Activity Sequence Analysis

This program selects a single activity of one operator for analysis. The activity selected is included if it is recorded as the first, second or third activity variable. The activity is selected by modifying the value of a variable in the program listing. The program prints out a sequence consisting of the code number of the activity, and a number indicating the duration (in sample time units) over which the activity was consecutively observed, followed by the number zero, indicating that the activity was not observed, accompanied by a number which indicates the duration in sampling interval units over which the activity was not observed. The program listing and a sample output are presented in Appendix C.

2.3.5 Multiple Activity Sequence Analysis

This program allows the researcher to select a set of four activities from those coded into the file. The researcher establishes a dominance order among these four activities, which means that if two or more of the selected activities have been recorded in the same sampling interval, only the activity which is higher on the order is selected. Then, for a particular operator who is selected by changing the value of a variable in the listing, the program generates transition matrices and a sequential listing of the four selected activities, along with a fifth activity category, coded zero, which represents any other activities.

One transition matrix records the frequency and proportions of transitions among the five activity classes at successive sampling intervals, which means that all transitions are recorded, including those which leave the activity unchanged (recorded on the main diagonal). The second output is a sequence consisting of the code

number of each successively encountered activity (including the "other" category coded as zero), accompanied by a variable which indexes the duration in sampling interval units over which that activity was successively observed. This listing is used as data for the FORTRAN program which tests for the order of the transition matrix. The third transition matrix records the transitions among pairs of successive activities: only transitions from one activity to a different activity are recorded and counted, and the main diagonal of the matrix is empty. This program is presented in Appendix C.

2.3.6 Stochastic Modeling Program

The input to this program is the sequence lists generated by the Position Sequence Analysis program or the Multiple Activity Analysis program. The stochastic modeling program carries out statistical tests to determine the order of dependencies among successive activities, that is, to determine the order of the Markov chain.

Markov chain model testing requires large numbers of observations in order to obtain reliable results. In order to carry out the analyses it was necessary to reduce the dimensionality of the original matrices. For example, to test for first-order versus second-order dependencies, it is necessary to consider three-step transitions. Three-step transition matrices have n^3 cells, where n is the number of categories of activities. If the number of categories is four, sufficient data (approximately five or more observations per cell) must be available in most of 64 cells to carry out the tests. Sufficient data were available to carry out these tests on activity sequences for the Captain, first mate and second mate of all three ships. Position analyses were carried for the Captain, first mate and second mate aboard the Arctic and Thuleland.

For these tests, the activity categories used for the Arctic and the Thuleland were visual observation, radar, communications, and navigation. For the Kigoriak the categories were visual observation, radar, communication and manual control. The position categories are shown along with the bridge layouts in Appendix A.

The program tested for the order of the chains by calculating chi-square statistics to compare the observed transition probabilities with the expected probabilities for a given order of Markov chain. To compare zero- versus first-order dependency the observed value of the chi-square statistic is compared with chi-square on $(n-1)^2$ degrees of freedom, where n for this data is the number of different positions or activities, typically four. To compare first- versus second-order or higher-order dependency the observed value of chi-square is compared with chi-square on $n(n-1)^2$ degrees of freedom. Our program computes the observed value of the chi-square statistics. The testing of the order of the dependency is carried out by using standard statistical tables.

If the data exhibit first-order dependency, and if the second chi-square test is significant, then the data show sequential dependencies of three or more successive positions or activities. The second test does not determine the exact limits of this dependency.

3. RESULTS

3.1 Scope and Reliability of the Data

Eighty two episodes were recorded. Forty-five of these were recorded aboard the M.V. Arctic, eighteen aboard the M.S. Thuleland, and nineteen aboard the M.V. Canmar Kigoriak. The episodes recorded aboard the Arctic spanned two seasons. Five episodes were recorded in June-July 1983 and forty episodes were recorded in October 1983. The episodes aboard the Thuleland were recorded in September 1984 and the episodes aboard the Kigoriak were recorded in October 1984.

A total of 9925 individual cases (15-second sampling units) was recorded. Of these 5588 were recorded aboard the Arctic, 1610 were recorded aboard the Thuleland, and 2727 were recorded aboard the Kigoriak.

The data are presented as percentages of sampling intervals during which a given position or activity was recorded. The standard deviation (SD) of a proportion p (equivalent to a percentage) equals $[p(1-p)/N]^{1/2}$. N is the number of sampling intervals over which the percentage was recorded. The percentages obtained from repeated sampling of the same series of events will lie within two standard deviations of the obtained percentage about 96 percent of the time. The standard deviations of the percentages recorded in this study are small, falling in the range of 0.2 to 7 percent. This is because the number of cases is almost always very large, ranging from about 175 to over 2000 per proportion. For every table of data presented, the largest SD calculated for the percentages found in that table is reported as a footnote. This enables the reliability of comparisons made within the table to be estimated. A difference between tabled percentages which is three times as large as the largest standard deviation in the table is unlikely to have occurred as a result of chance more than about one time in one thousand. Few if any of the comparisons suggested by the data of this study were anticipated on the basis of hypotheses, so the hypothesis-testing model of statistical inference is not appropriate. Our description of the results emphasizes the patterns which are found to be important based on statistical and consistency criteria.

3.2 Principles of Data Partition

Environmental. The data were classified according to two environmental variables: ice cover and light. Ice cover was classified as one of five categories for every episode. The categories were: open water, bergy water, new ice, first-year ice, and old (multiyear) ice. Very few differences in overall positions or activities were observed as a function of ice type, and so the data were collapsed into three descriptive categories: open water, bergy water, and ice cover (any type).

A natural division in illumination conditions occurs at 3.4 cd/m^2. Above this value, the eyes are adapted to photopic (cone) vision, while below this value, scotopic (rod) and cone vision are both functional, down to a level of less than .03 cd/m^2, where rod

vision alone is functional. The latitude, longitude, date, local time and cloud cover all influenced the level of illumination prevalent when the data were recorded. Frequent luminance measurements were obtained aboard all three ships on the same days and at about the same hours when the task analysis data were being recorded. A plot of luminance as a function of local time for each ship on each voyage (Figure 1) was used to find local time cutoff points for classifying each episode into day (> 3.4 cd/m^2) and night (<= 3.4 cd/m^2) categories.

Ships. The M.V. Arctic is a 28,000 dwt Arctic Class 2 (ASPPR) icebreaking bulk carrier. Her length O.A. is 209.55 metres, and breadth is 22.93 metres. A single main engine drives a controllable pitch propeller in a KORT nozzle. The ship is equipped with a Wartsila bubbler system.

The M.S. Thuleland is a 30,000 dwt Arctic Type A (Baltic 1A) ice-strengthened bulk carrier. Length O.A. is 186 metres, and breadth is 26.5 metres. The Thuleland has a single main engine which drives a single fixed pitch propeller. There is a bow thruster.

The M.V. Canmar Kigoriak is a 6550 dwt Arctic Class 3 (Lloyd's 100A1) icebreaking tug, with a single controllable pitch propeller in a nozzle. The propeller is driven by two diesel engines. The Kigoriak has a hull wash lubrication system, a bow thruster and a stern thruster. She is 90 meters long, and has a beam of 19.25 metres over the flared icebreaking bow.

The ship's wheelhouses have were described in Section 2, and illustrations were presented in Appendix A. The data from each ship are presented separately.

Personnel. Data were collected for all the officers present on the bridge. The data presented here includes the episodes for the Captain and the watchkeeping officers, and for the Reserve Captain when sufficient data were available to justify analysis. Within each ship, the data recorded for each person are summarized separately.

On the transiting bulk carriers, the helmsman played a watchkeeping role when the ships were on automatic pilot. Helmsman's activities and positions were recorded when he was not steering, and these positions and activities are discussed where appropriate.

3.3 Dependent Variables

3.3.1 Position

The position for each officer was originally defined as any one of twelve or thirteen separate locations on the bridge of each ship, in addition to position classifications "in transit" and "off bridge", which were used where appropriate. These positions were recoded into fewer, larger categories for frequency and transition analysis. The categories varied slightly among ships, reflecting the physical difference in bridge layouts.

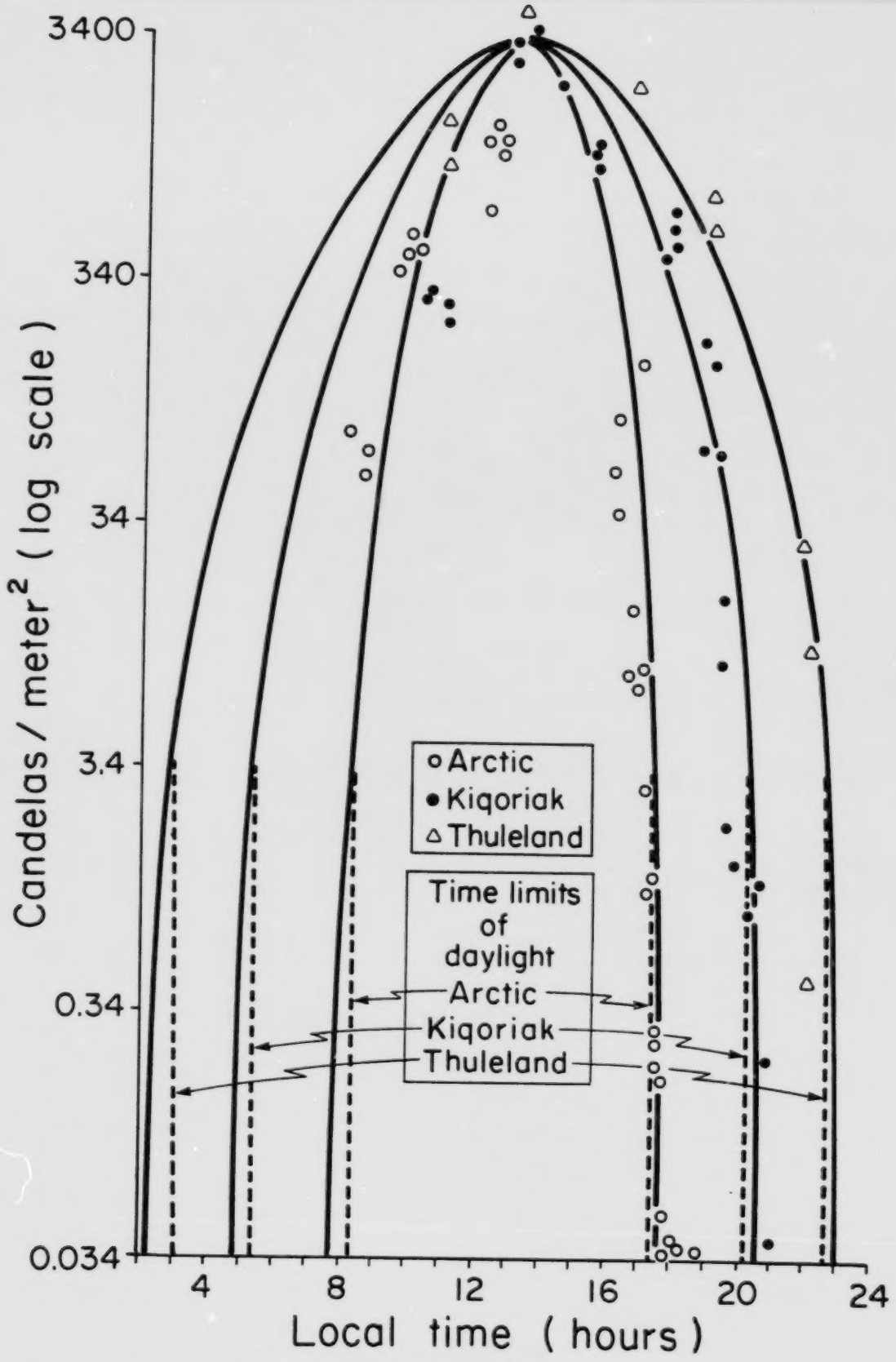

Figure 1 Sky luminance as a function of local time for fall voyages of M.V. Arctic, M.S. Thuleland, and M.V. Canmar Kigoriak

M.V. Arctic. Five positions were defined aboard the Arctic: port wing, main console, starboard radar, starboard wing and chart table. The starboard radar position contained two radar displays. The chart table position included both the conventional chart table and the newly installed instrument used to magnify filmstrips and facilitate the study of the SLAR (side-looking airborne radar) imagery. This instrument was located on the starboard side of the after part of the bridge, across from the chart table. There was a radar screen alongside the inboard edge of the chart table in the after part of the bridge.

M.S. Thuleland. Four positions were defined aboard the M.S. Thuleland. They were: port wing, starboard wing, chart table and starboard radar (aft). The port and starboard wing positions were forward; the chart and radar positions were aft. A radar display was located on the port wing.

M.V. Canmar Kigoriak. Four positions were defined aboard the Kigoriak: port wing, starboard wing, forward control position, and chart table. A radar display was located at the forward control position, and additional radar displays were located at the chart table position. A facsimile copier and a ship-to-shore telephone were located at the port wing position.

3.3.2 Activities

Activities were recoded into five classes for purposes of transition and frequency analysis. The same classes were used for the data from all ships. The activity classes were: visual, radar, communications, control and navigation. The visual activity class included all records of unaided visual observation, plus records of binocular and night vision device use. The radar class included all recorded use of the radar displays. The communications class included both voice and instrumental (phone, P.A. and radio) communications. Control activities included all console manipulation and direct manoeuvring through the control of tiller, wheel or propeller pitch and shaft rpm. Navigation activities included all the functions which took place at the chart table.

3.3.3 Analyses

The data were analyzed in terms of the percentage of occurrence of positions and activities by ship, officer, ice cover, and light condition. In addition, the joint distribution of positions for pairs of officers were determined and analyzed for statistical independence. The sequences of activities and positions were analyzed to determine the transition probabilities between successive activities or positions, the statistical properties of the frequency distribution of activity lengths and inter-activity intervals, and the statistical properties of the overall sequences of activities and positions.

3.4 M.V. Arctic

3.4.1 Positions

By officer. Officers divided their time almost equally among the four forward locations: port wing, main console, and starboard wing, which included the two forward radar monitors. The median proportions for the five officers (Captain, Reserve Captain and three watch officers) were: port wing, 23, main console, 13, starboard wing, 30 (radars, 20; non-radar area, 10). A median 33 percent of officers' time was spent in the chart table and aft bridge areas. The first, second and third mates spent 33, 39 and 46 percent, respectively, of their time at the chart table. The Captain and Reserve Captain spent 6 and 20 percent, respectively.

Table 2 Percent of Time Spent by Each Officer at Each Position, Summed over all Episodes: M.V. Arctic

Officer	Position				
	Port	Main Console	Stbd. Radar	Stbd.	Chart
Captain	23	12	23	36	6
Reserve Captain	25	25	20	10	20
First Mate	31	13	15	8	33
Second Mate	13	22	19	8	39
Third Mate	8	10	23	12	46

Note: The largest SD is 0.8 percent.

The helmsman was recorded at the port wing 53 percent of the time, at the after part of the bridge (which included the steering stand) 39 percent of the time, and in other locations, 9 percent of the time.

Effect of Light and Ice. The distribution of sample sizes made it possible to compare the positional preference of all officers in daytime conditions in bergy water. Under these conditions, there was a clear tendency for all officers except the Captain to prefer the starboard to the port wing; the starboard wing median was 28 percent, compared to 13 percent for the port wing. The median proportion at the starboard radar location was 28 percent. The second and third mates spent 48 and 59 percent of their time, respectively, at the chart table or in the after part of the bridge. The Captain, Reserve

Table 3 Percent of Time Spent by Each Officer at Each Position during Daytime Bergy Water Episodes: M.V. Arctic

Officer	Position				
	Port	Main Console	Stbd. Radar	Stbd.	Chart
Captain	28	44	5	8	15
Reserve Captain	19	20	28	9	25
First Mate	13	39	23	5	19
Second Mate	3	15	32	1	48
Third Mate	10	12	13	7	59

Note: The largest SD is 4 percent.

Table 4 Percent of Time Spent by Second and Third Mate at Each Position under Different Ice Cover in Daylight: M.V. Arctic

Ice Cover	Position				
	Port	Main Console	Stbd. Radar	Stbd.	Chart
		Second Mate			
Open water	4	37	8	1	50
Bergy water	3	15	32	1	48
Ice cover	27	12	20	17	24
		Third Mate			
Open water	4	6	30	11	49
Bergy water	10	12	13	7	59
Ice cover	10	15	29	8	37

Note: The largest SD is 3 percent.

Captain and first mate spent 15, 25 and 19 percent of their time, respectively at the chart table. The helmsman spent 53 percent of his time at the port wing, 35 in the after part of the bridge, and 11 percent elsewhere.

Reliable position data were obtained for the second and third mates in open water, bergy water and ice under daylight. Under all of these conditions, the starboard wing, including the radar locations, was preferred to the port wing no less than 1.5 times and up to as much as ten times. The proportion of time spent at the chart table was again high over all conditions, ranging from a low of 24 to a high of 59 percent, but in ice, this percent was lower for both officers: from 49 to 24 percent for the second mate, and from 50 to 37 percent for the third mate. At night, the first mate spent less time at the chart table in ice than in open or in bergy water.

No clear positional differences associated with the day-night distinction were observed for all officers. The Captain was observed to favour the port wing relative to the starboard wing at night; but the opposite was observed of the third mate.

Table 5 Percent of Time Spent by First Mate at Each Position under Different Ice Cover at Night: M.V. Arctic

Ice Cover	Position				
	Port	Main Console	Stbd. Radar	Stbd.	Chart
Open water	19	25	7	12	37
Bergy water	0	2	20	31	47
Ice Cover	42	6	16	6	30

Note: The largest SD is 7 percent.

In open water and bergy water at night, the helmsman vastly increased the time spent at the port wing, and vastly decreased the time spent in the after part of the bridge, by comparison to daytime. Conversations with the helmsmen made it clear that their responsibility to keep a good watch was particularly strongly felt at night. In ice, the ship was on manual steering and the helmsman spent all his time at the wheel.

Joint Positions. The Captain and first mate occupied the same position on the bridge 27 percent of the time, where 23 percent would be expected if the two officers chose their positions independently of one another. This small tendency towards occupying the same position was statistically significant by conventional tests ($p < .02$, Chi-

Table 6 Percent of Time Spent by Captain at Each Position while in Ice Cover during Day and Night: M.V. Arctic

Light	Position				
	Port	Main Console	Stbd. Radar	Stbd.	Chart
Day	7	7	21	60	5
Night	35	11	28	23	4

Note: The largest SD is 2 percent.

square analysis). The Captain and the third mate occupied the same position on the bridge 21 percent of the time, as opposed to the 17 percent joint occupancy expected if each officer chose his position independently. This difference in favor of occupying the same position was also statistically significant by the same test at $p < .001$.

Stochastic modeling. Transition matrices among positions were calculated for the Captain, first mate and second mate. These matrices are presented in Appendix D. The transition matrices for the Captain showed significant second or higher-order dependencies ($p < .005$). The transition matrices for the other officers failed to demonstrate any sequential dependencies. For the first and second mates, present positions were best predicted from the overall proportions of positions occupied, and were independent of the previously occupied positions.

The most frequent three-position sequences for the Captain were starboard wing--chart table--starboard wing, chart table--starboard wing--chart table, and starboard wing--main console--starboard wing. These three sequences total 53 percent of all of those recorded. It is interesting to note that the most frequently used radar was on the starboard wing, along with clear access to the forward windows. These movement sequences establish the importance of movement from the navigation area to a place where visual and radar observation are possible.

Lack of significant sequential dependencies in the movement patterns of the first and second mates means that their position at a given time can only be predicted from the overall probability of occupying a given position. It also means that there was no discernible pattern to their movements.

3.4.2 Activities

By Officer. The most frequently recorded activity was visual, followed by navigation, radar, control and communication in that order. Visual activity was recorded on a median 52 percent of observations, navigation, 32, radar, 14, control, 4, and communication, 4.

Table 7 Percent of Sampling Intervals for each Activity, Summed over all Episodes: M.V. Arctic

Officer	Activity				
	Vision	Radar	Communication	Control	Navigation
Captain	70	18	18	5	5
Reserve Captain	86	8	4	5	5
First Mate	52	14	3	3	32
Second Mate	45	8	6	4	42
Third Mate	33	19	3	3	47

Note: The largest SD is 2 percent.

The Captain and Reserve Captain had the highest visual observation proportions, at 70 and 86, respectively. The watch officers were lower at: first mate, 52, second mate, 45, and third mate, 33. The converse was true for navigation activities. The Captain and Reserve Captain recorded 5 percent, while the three watch officers engaged in navigation activities on 32, 42 and 47 percent of the observations, respectively.

The helmsman was recorded as making visual observations on 93 percent of the recorded sampling sessions. This was true under autopilot conditions in open water and bergy water; in ice the helmsman was always at the steering stand.

Console operations were recorded on between 3 and 5 percent of the sample across all officers: a low and uniform percentage. Radar use varied between 8 and 19 percent of the time. Communications were recorded most frequently, at 18 percent, for the Captain; the others ranged from 3 to 6 percent.

Effect of Light and Ice. In bergy water in daytime, patterns of activity very similar to those overall were observed. Visual observations were recorded most frequently from the Captain, Reserve Captain and first mate at 66, 76 and 75, respectively. The second and

Table 8 Percent of Sampling Intervals for each Activity during Daytime Bergy Water Episodes: M.V. Arctic

Officer	Activity				
	Vision	Radar	Communication	Control	Navigation
Captain	66	7	20	0	8
Reserve Captain	76	13	4	8	5
First Mate	75	3	2	0	21
Second Mate	34	13	10	2	49
Third Mate	31	11	4	5	56

Note: The largest SD is 5 percent.

Table 9 Percent of Sampling Intervals for each Activity under Different Ice Cover in Daytime: M.V. Arctic

Ice Cover	Activity				
	Vision	Radar	Communication	Control	Navigation
			Second Mate		
Open Water	49	9	3	10	35
Bergy Water	34	13	10	2	49
Ice cover	54	5	6	0	37
			Third Mate		
Open Water	27	29	0	1	45
Bergy Water	31	11	4	5	56
Ice cover	41	18	5	0	39

Note: The largest SD is 4 percent.

third mate recorded 34 and 31 percent, respectively. Navigation activity again showed the converse: Captain and Reserve Captain at 8 and 5, and watchkeeping officers at between 21 (first mate) and 56 (third mate) percent. The pattern of radar, communication and control was similar to the pattern when the data were summed over all conditions.

The second and third mates were observed in daytime in open water, in bergy water and in ice. Both officers increased their visual observation in ice as opposed to either bergy water or open water; the proportion of navigation activities of the second mate did not noticeably decrease but the navigation proportion for the third mate did decrease from a median of 54 to 35 percent. (Both officers, however, decreased the amount of time spent in navigating positions at the after part of the bridge).

Summaries of the data on visual observation and radar use as a function of ice type are found in Figures 6 and 7. These figures present the median and range across all officers of the proportion of sampling intervals on which visual observation and radar use were recorded under open water, bergy water, new ice, first-year ice, and old ice conditions. The data are presented in comparative form, for M.V. Arctic and M.S. Thuleland. Radar use increased greatly in first year ice, while visual observation remained relatively constant across all navigating environments, for officers aboard the Arctic.

The Captain increased the amount of time spent at night at the radar to 34 percent from 7 percent in daytime. The first mate, who was recorded at night across all three ice conditions, decreased visual activity in ice, from a median of 57 in open water and bergy water, to 42 in ice; and increased radar use, from a median of 6 percent in bergy water and open water to 22 percent in ice. Among the four officers where this comparison could be made, radar use increased at night from 1.2 times to 5 times as frequently as in daytime. In short, radar use increased at night; and, at night, radar use increased in ice as opposed to open or bergy water.

Table 10 Percent of Sampling Intervals for each Activity by the Captain at Each Activity while in Ice, during Day and Night: M.V. Arctic

Light	Activity				
	Vision	Radar	Communication	Control	Navigation
Day	81	7	25	5	4
Night	58	34	11	6	5

Note: The largest SD is 2 percent.

Table 11 Percent of Sampling Intervals for each Activity by First Mate at Each Activity under Different Ice Cover at Night: M.V. Arctic

Ice Cover	Activity				
	Vision	Radar	Communication	Control	Navigation
Open water	65	1	1	4	34
Bergy water	50	11	7	30	30
Ice cover	42	22	4	1	34

Note: The largest SD is 7 percent.

The helmsman, under open water and bergy water conditions, increased his visual observations recorded from a median 91.5 percent to a median 97 percent, and other activities were reduced proportionately.

Joint Activities. Thirty percent of the activities recorded for the Captain and the first mate were the same at a given sampling interval. Most of the identical activities which occurred at the same time were radar or visual. Nine percent of all activities were joint navigation activities. Forty two percent of the first mate's activities while he and the Captain were simultaneously present on the bridge were navigation activities: most of these (87 percent) occurred while the Captain was making radar or visual observations.

Forty seven percent of the third mate's activities while the Captain was on the bridge were navigation: of these, 56 percent occurred while the Captain was making radar or visual observations. The Captain and third mate were jointly engaged in navigating activities 19 percent of the time; their overall sharing of identical activities was 43 percent.

Data summarized for each episode were plotted against the episode local time to determine whether there was variation as a function of local time, and consequently as a function of light level. The only effect clearly observable was a tendency for binocular use to peak in the middle daylight hours (Figure 2). Activity proportions at each episode were plotted against each other to determine whether any significant relationships among activities were apparent. As suggested earlier in the summary data, a relationship was observed over all episodes for each officer between the proportion of time spent in visual activities and the proportion spent in navigating activities. They were inversely related (Figure 3). Partial correlations between visibility proportion and chart table activity,

controlling for non-operating time, ranged from -.53 to -.15 across the five officers (median -.35).

Total Visual Observations. The total number of visual observations made during each sampling interval by all members of the bridge crew was calculated and segregated by the number of crew on the bridge. A graph relating the total number of visual observations to the size of the bridge crew is presented as Figure 8, along with comparable data from M.S. Thuleland. The data presented are for navigating in bergy water. The data summed over all conditions are almost identical. It is apparent that there is a decrease in the total number of visual observations as the bridge crew increases from one to two, followed by an increase in the total number of visual observations at a rate which shows that, aboard the M.V. Arctic, each additional bridge crew member adds fewer additional visual observations than does the original single officer on watch.

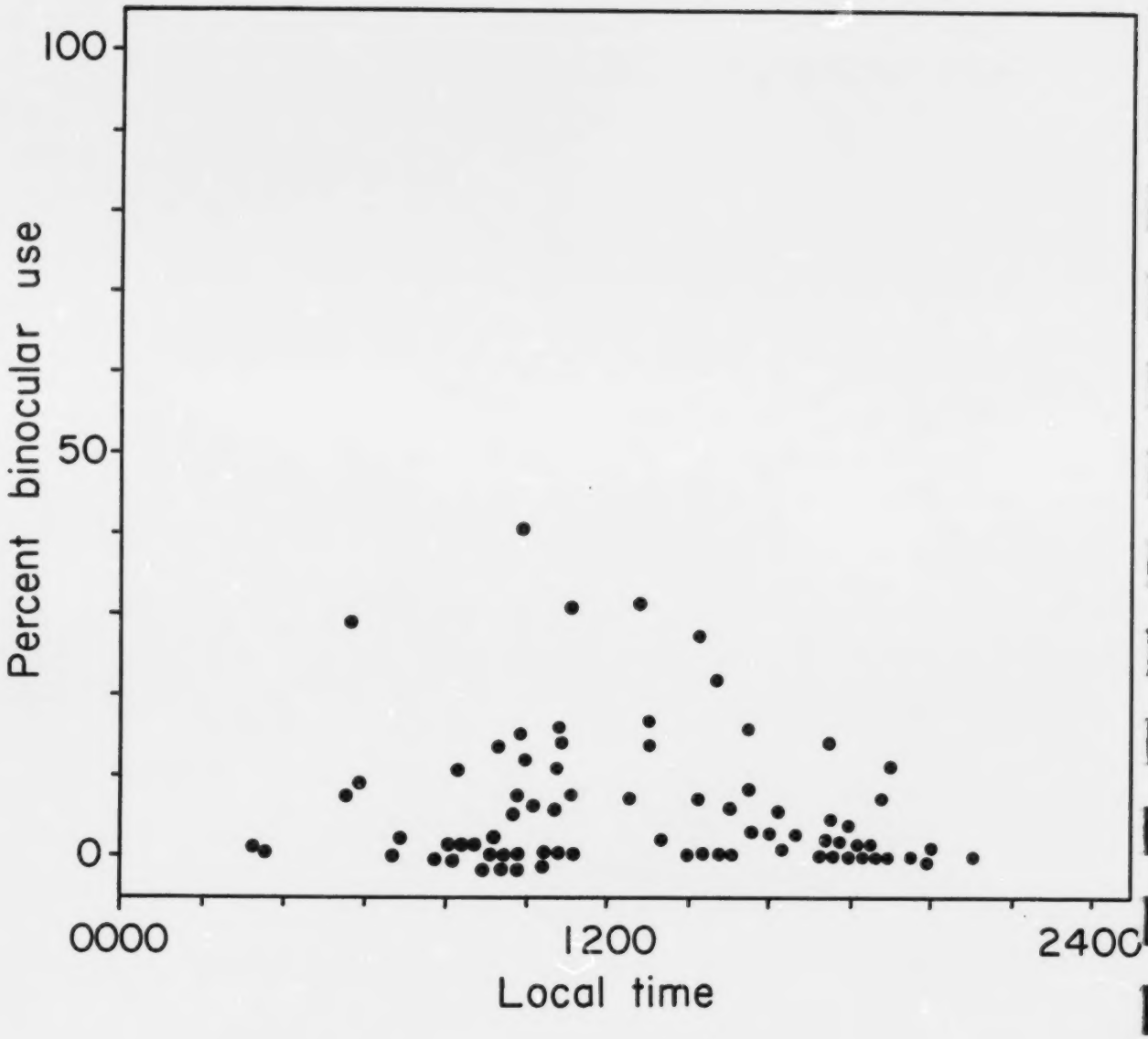

Figure 2. Percent binocular use as a function of local time: all episodes, all officers, M.V. Arctic

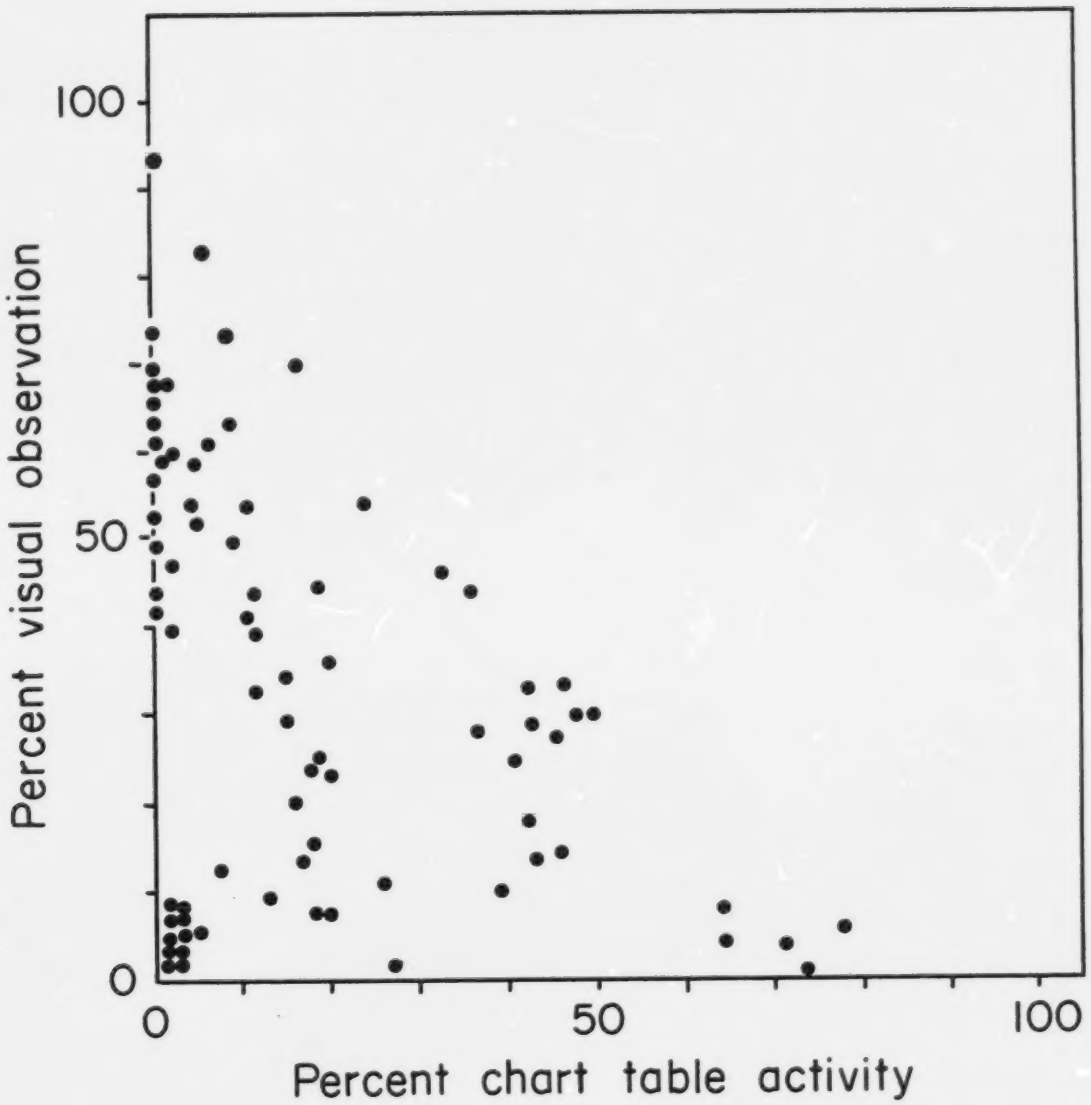

Figure 3. Percent visual observation per episode as a function of percent chart table activity per episode: all episodes, all officers, M.V. Arctic

Table 12. Mean Activity Length (AL) and Mean Inter-Activity Interval (IA) for Radar, Communication and Navigation. (Seconds): M.V. Arctic

Officer	Activity					
	Radar		Communication		Navigation	
	AL	IA	AL	IA	AL	IA
Captain	27	304	18	224	123	-
Reserve Captain	32	414	17	627	-	-
First Mate	28	330	21	642	133	-
Second Mate	-	-	22	606	197	-

Stochastic modeling. The pattern of sequential dependencies among activities repeated the pattern observed for the three officers' movements. The transition matrices are found in Appendix D. Significant second or higher-order sequences were observed for the Captain ($p < .005$). The most common activity sequences for the Captain were visual observation--communication--visual observation, communication--visual observation--communication, visual observation--radar--visual observation, and radar--visual observation--radar. This set of sequences accounted for 43 percent of the recorded second-order sequences.

No significant sequental activity dependencies were observed for either the first or the second mate. The order of occurrence of their activities as well as their positions was random, determined only by the overall probability of occurrence of the activity.

The distribution of activity durations and inter-activity lengths were calculated for Captain, Reserve Captain and first mate for the use of the conventional marine radar, and for communications activities combining the use of radio and the ship's internal communication system (phone and P.A.). The mean activity duration and inter-activity intervals for radar, communication and chart table activities are presented for four officers in Table 12. The median radar observation length across the three officers was 28 seconds; the median inter-observation interval was two minutes and six seconds. The distributions of radar observation durations were highly skewed. The inter-observation intervals were also skewed, with a few very long inter-observation intervals and fewer very short ones.

The Captain's radar activity duration and inter-observation intervals were compared for night and day. The observations were

longer, and the intervals shorter, at night. At night, the observations lasted an average 28 seconds, and the average interval between observations was four minutes 8 seconds; for daytime, the average observation lasted 25 seconds and the average interval between observations was seven minutes 18 seconds.

Communications durations and intervals were sampled across officers in the same way. The average duration of a communication was 23 seconds (median 15 seconds) and the average duration of the interval was ten minutes 6 seconds. The inter-observation intervals were more skewed, but still had a predominance of short inter-observation intervals and a small number of a long intervals.

3.5 M.S. Thuleland

3.5.1 Positions

By Officer. The port and starboard sides of the bridge were occupied about equally by the officers. Individual percentage of occupancy ranged from 22 to 47 on the port side, and from 4 to 50 on the starboard side. The port side had a forward mounted radar, and the starboard side had the steering stand and the main console.

The helmsman, whose steering station was to starboard, occupied the port wing 38 percent of the time and the starboard wing, 40 percent of the time. The distribution of officers across the forward part of the bridge was reasonably uniform.

Individual time spent at the chart table varied from 10 to 31 percent. The Captain and Reserve Captain spent 20 and 10 percent, crespectively; the watch officers ranged from a low of 14 percent (third mate) to a high of 32 percent (second mate). The starboard radar, positioned aft, was occupied between 6 percent (Captain) and 26 percent (second mate) of the time.

Table 13 Percent of Time Spent by Each Officer at Each Position, Summed Over all Episodes: M.S. Thuleland

Officer	Position			
	Port	Starboard	Chart	Stbd. Radar
Captain	42	33	20	6
Reserve Captain	38	40	10	12
First Mate	47	22	23	8
Second Mate	39	4	31	26
Third Mate	22	50	14	14

Note: The largest SD is 6 percent.

Effect of Ice. For five of the six officers and the helmsman (all officers except the Captain), ice reduced time spent at the chart table position and increased the time spent in the forward part of the bridge.

There was no evidence of consistent changes in position preference with a change in light from day to night, although the second mate spent less time at the chart table at night (Table 14).

Table 14 Percent of Time Spent by Reserve Captain and Second Mate at Each Position during Day and Night: M.S. Thuleland

Light	Position			
	Port	Starboard	Chart	Stbd. Radar
		Reserve Captain		
Day	26	55	10	10
Night	58	15	11	15
		Second Mate		
Day	25	3	47	25
Night	54	4	15	27

Note: The largest SD is 4 percent.

Joint Distributions. The Captain and third mate, who were recorded jointly on the bridge together for about two hours, showed a small tendency to stand in the same bridge location; slightly more frequently on the port wing together than expected if each officer had chosen his own position independently, but the effect was numerically very small, although significant at $p < .05$ by conventional statistical tests (Chi-square).

Stochastic Modeling. Transition matrices for movements among positions were calculated for three officers and are presented in Appendix D. All of the M.S. Thuleland officers' first-order sequential dependencies were significant ($p < .005$, for Captain, first and second mate) but the officers' data did not demonstrate any significant second or higher-order dependencies. Thus, the present position of Thuleland officers depends only on their immediately preceding position.

The Captain's most frequent movements were from one side of the bridge to the other. His next most frequent movements were from the chart table to the port side, and back again. It should be noted that a radar was located at the port side forward bulkhead. His other frequent movement was from the starboard radar (mounted towards the

after part of the bridge) to the chart table.

The first mate's movement pattern was similar to the Captain's. The most frequent movements were from port to starboard and back. The next most frequent were back and forth between the chart table and the starboard wing. But, unlike the captain's movements, the mate's movements also described a circular route between the port wing and the starboard radar, and from the starboard radar to the starboard wing.

The second mate moved most frequently back and forth between the chart table and the starboard radar. His next most frequent movements were from the starboard to the port wing, and from the port wing to the starboard radar. The movements described for each officer accounted for about seventy percent of all the positions recorded.

3.5.2 Activities

By Officer. The predominant activity for all officers was visual observation, which was recorded on between 91 percent and 53 percent of the sampling intervals for the personnel on the bridge. The high percentage was for the Reserve Captain and the low percentage was for the second mate, who had the largest percentage (26) of navigating activity. Radar observation ranged from 6 percent (Captain) to 23 percent (second mate) of sampling intervals, and navigation activity ranged from 6 percent (Reserve Captain) to 26 percent. Communication frequency ranged between 11 and 20 percent across the officers, and control activities were a uniform low 1 to 7 percent. Table 15 summarizes these data.

Table 15 Percent of Sampling Intervals for each Activity, Summed Over all Episodes: M.S. Thuleland

Officer	Activity				
	Vision	Radar	Communication	Control	Navigation
Captain	90	6	11	1	15
Reserve Captain	91	16	20	3	6
First Mate	89	10	15	1	19
Second Mate	53	23	14	1	26
Third Mate	93	14	11	7	13

Note: The largest SD is 2 percent.

Effect of Light and Ice. With the exception of the Captain, the proportion of navigation activities decreases as the ice cover changes from open water to bergy water to ice. There was also a tendency to increase radar use at night, and to decrease navigation activity at night. This was consistently true for the two officers (Reserve Captain and second mate) from whom reliable activity data was available both at day and at night. The helmsman also increased his radar use at night. Table 16 summarizes these data.

Table 16 Percent of Sampling Intervals for each Activity during Day and Night: M.S. Thuleland

Light	Activity				
	Vision	Radar	Communication	Control	Navigation
			Reserve Captain		
Day	96	11	16	4	8
Night	81	24	27	1	4
			Second Mate		
Day	42	14	5	1	42
Night	65	31	23	1	11

Note: The largest SD is 4 percent.

Figures 6 and 7 present in comparative form the proportion of sampling intervals on which visual observation and radar activities were recorded for all officers aboard the M.V. Arctic and M.S. Thuleland. It is clear that aboard the Thuleland, increasing ice cover leads to an increase in the proportion of visual observation, while radar use remains relatively low and constant across conditions. The radar usep pattern is different from the one observed aboard M.V. Arctic, where radar was used heavily in first-year ice.

Joint Distributions. The activities of the Captain and third mate, recorded simultaneously for about two hours, indicate that the two officers were making visual observations simultaneously on about 94 percent of the sampling intervals. One or the other officer was making visual observations most of the remaining time; very few occasions were recorded on which both officers were carrying out navigating activities at the chart table.

Variables summarized for each episode were plotted against the local time to determine whether there were any effects dependent on general illumination level, and the variables were plotted against

each other within each episode to determine whether there were any dependences among position choices over episodes. Binocular use tended to peak at midday, as was true of the data from the Arctic. This relationship is illustrated in Figure 4.

The proportion of time spent at the chart table was inversely related to the proportion of time spent in making visual observations. Partial correlations between time spent in visual observation and time spent in chart table activities were calculated, correcting for the effect of time spent in non-operating activities. This was done to eliminate possible confounding effects of general level of activity on the obtained relationship between visual activity and chart table activity. The data were from all episodes for each of the watchkeeping officers. The correlations for the captain and the three watchkeeping officers ranged from -.75 to -.55, confirming the strong negative relationship between time spent in chart table activities and time spent in visual observation. These data are summarized in Figure 5.

Total Visual Observations. The total number of visual observations made by all members of the bridge crew on each sampling interval was calculated for all episodes and segregated by the number of crew members on the bridge. The graph relating the total number of visual observations to the number of bridge crew is presented in Figure 8, along with comprative data from M.V. Arctic. The data presented are for navigation in bergy water, but the data over the total sample are almost identical. It can be clearly observed that the rate of increase of visual observations as a function of number of bridge crew is greater aboard M.S. Thuleland than aboard M.V. Arctic.

Stochastic Modeling. Activity transition matrices were generated for three officers, and they are presented in Appendix D. The pattern of activity dependence was the same as the pattern of position dependence. First-order sequences were significant for the captain and for both mates, while no second or higher-order dependencies were significant for any officer. For both the captain and the first mate, transitions back and forth between visual observation and communication were most frequent, followed by transitions back and forth between visual observation and navigation activities. The most frequent transitions for the second mate were between visual observation and radar use. The next most frequent was between navigation activities and radar, followed by transitions back and forth between vision and communications. For all of these officers, the activity transitions which were described accounted for about sixty percent of those recorded.

Distributions of activity durations and inter-activity intervals were plotted for radar use and for communication, as was done with the data from the M.V. Arctic. The radar observation mean intervals ranged from 36 seconds to 48 seconds over the three officers, and the mean inter-observation intervals ranged from four minutes 10 seconds to nine minutes 15 seconds. Both the duration and inter-activity interval distributions were highly skewed. The duration of communications ranged from 27 seconds to 40 seconds across the two officers from whom enough communications data were available.

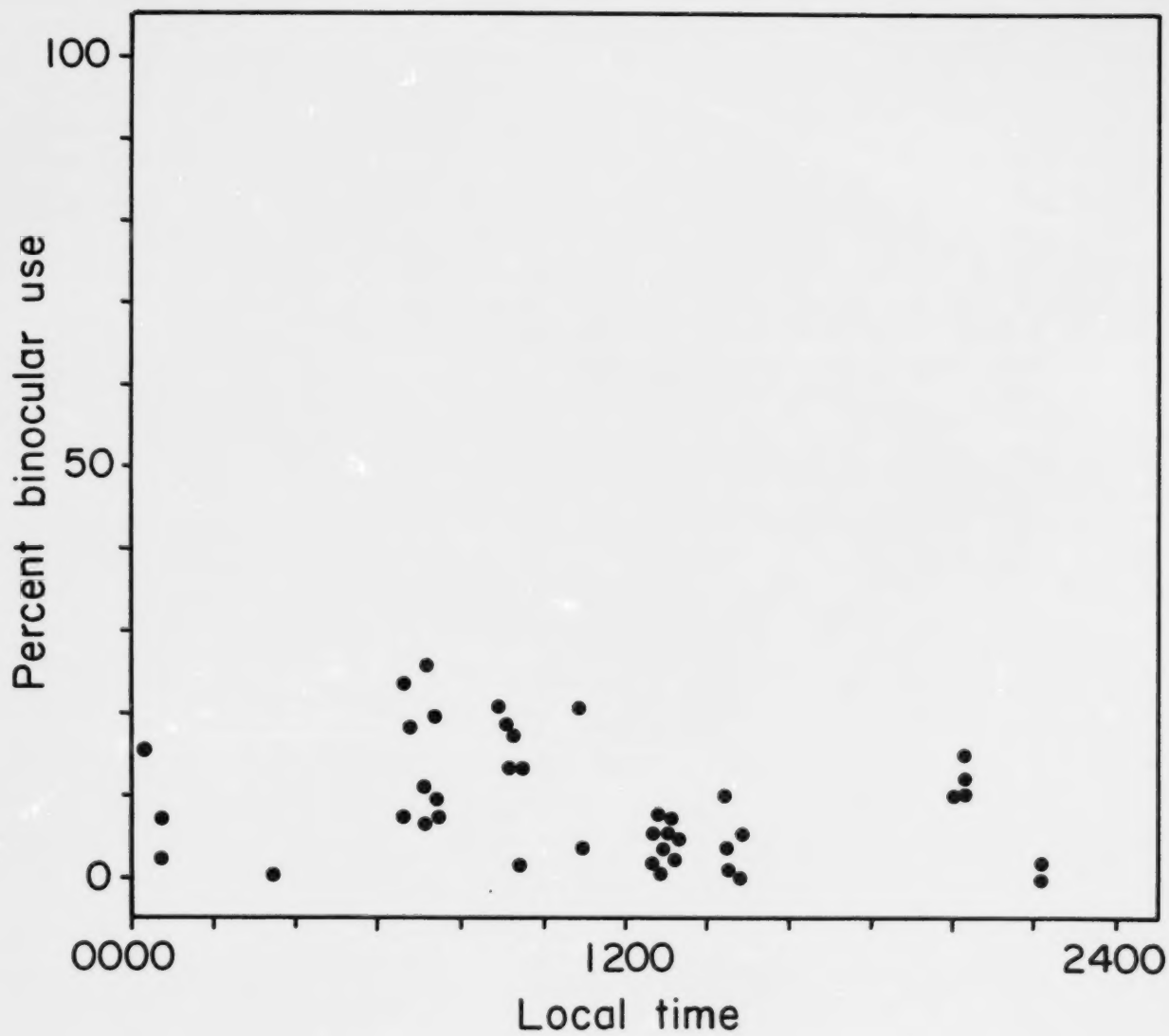

Figure 4. Percent binocular use per episode as a function of local time: all episodes, all officers, M.S. Thuleland

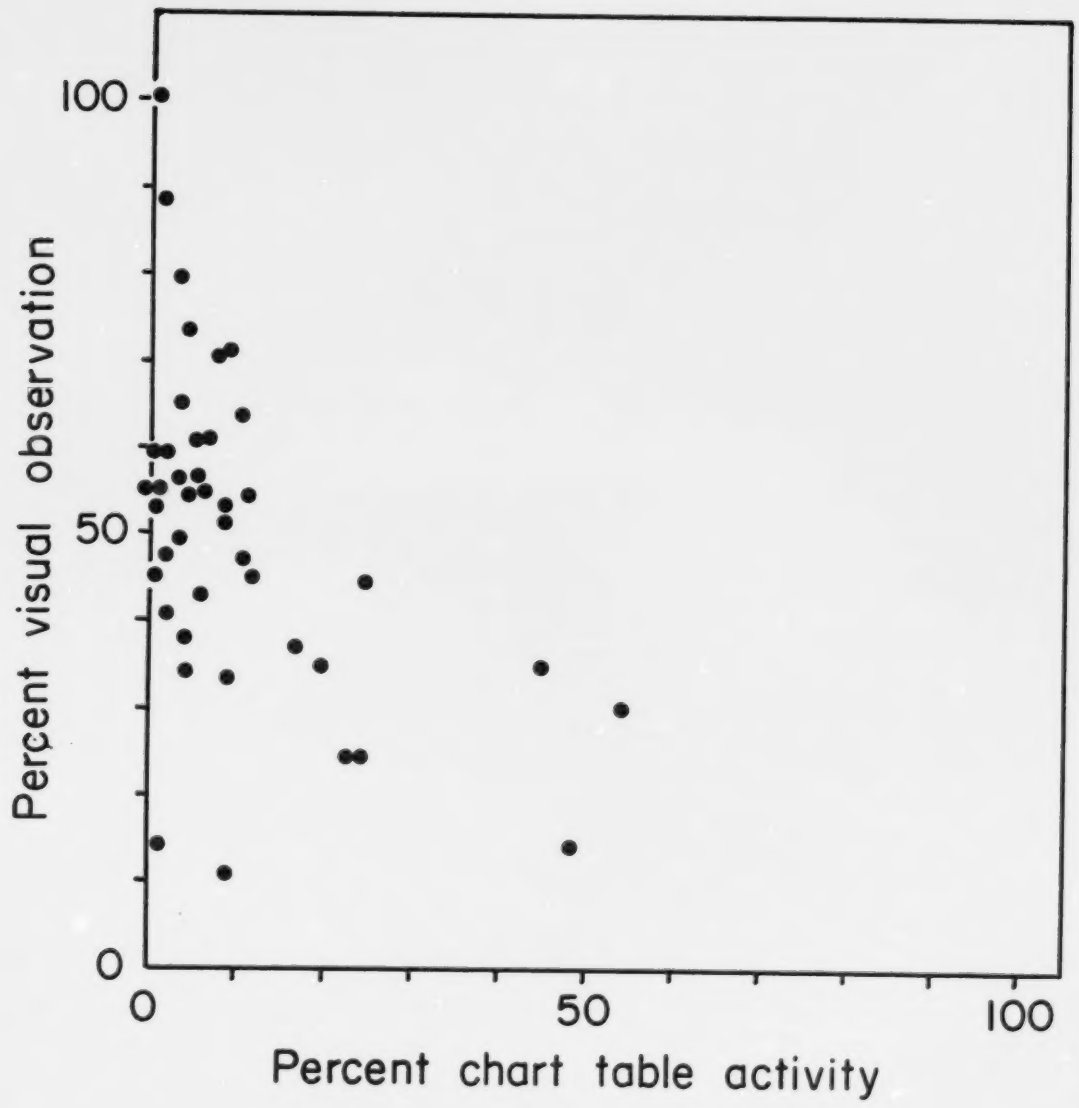

Figure 5. Percent visual observation per episode as a function of percent chart table activity: all episodes, all officers, M.S. Thuleland

Table 17 Mean Activity Length (AL) and Mean Inter-Activity Interval (IA) for Radar, Communication and Navigation. (Seconds): M.S. Thuleland

Officer	Activity					
	Radar		Communication		Navigation	
	AL	IA	AL	IA	AL	IA
Captain	36	555	40	1260	97	-
First Mate	40	550	27	227	46	-
Second Mate	48	250	-	-	74	-

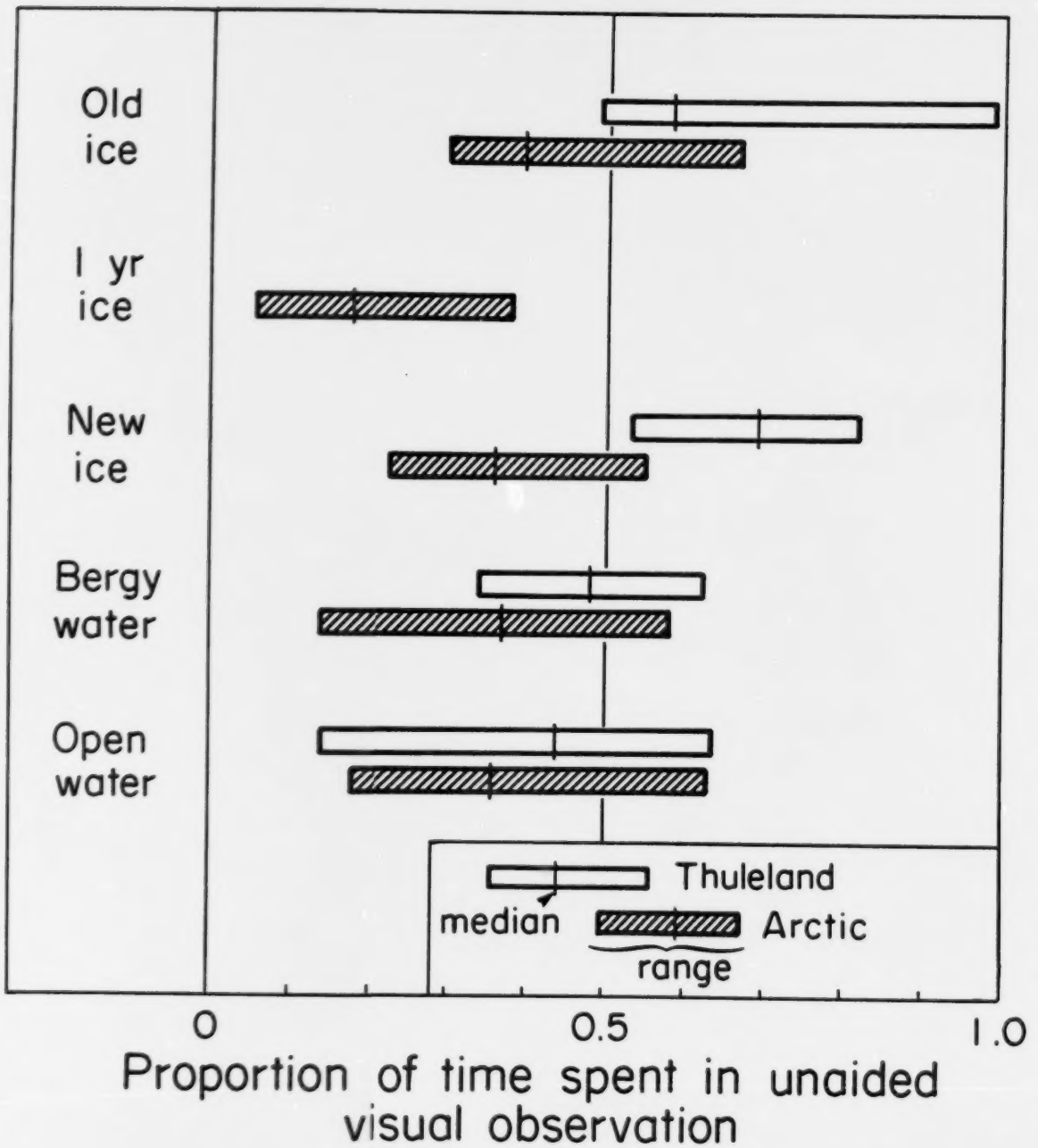

Figure 6 Proportion of time spend in unaided visual observations in different ice conditions, all officers, M.V. Arctic and M.S. Thuleland

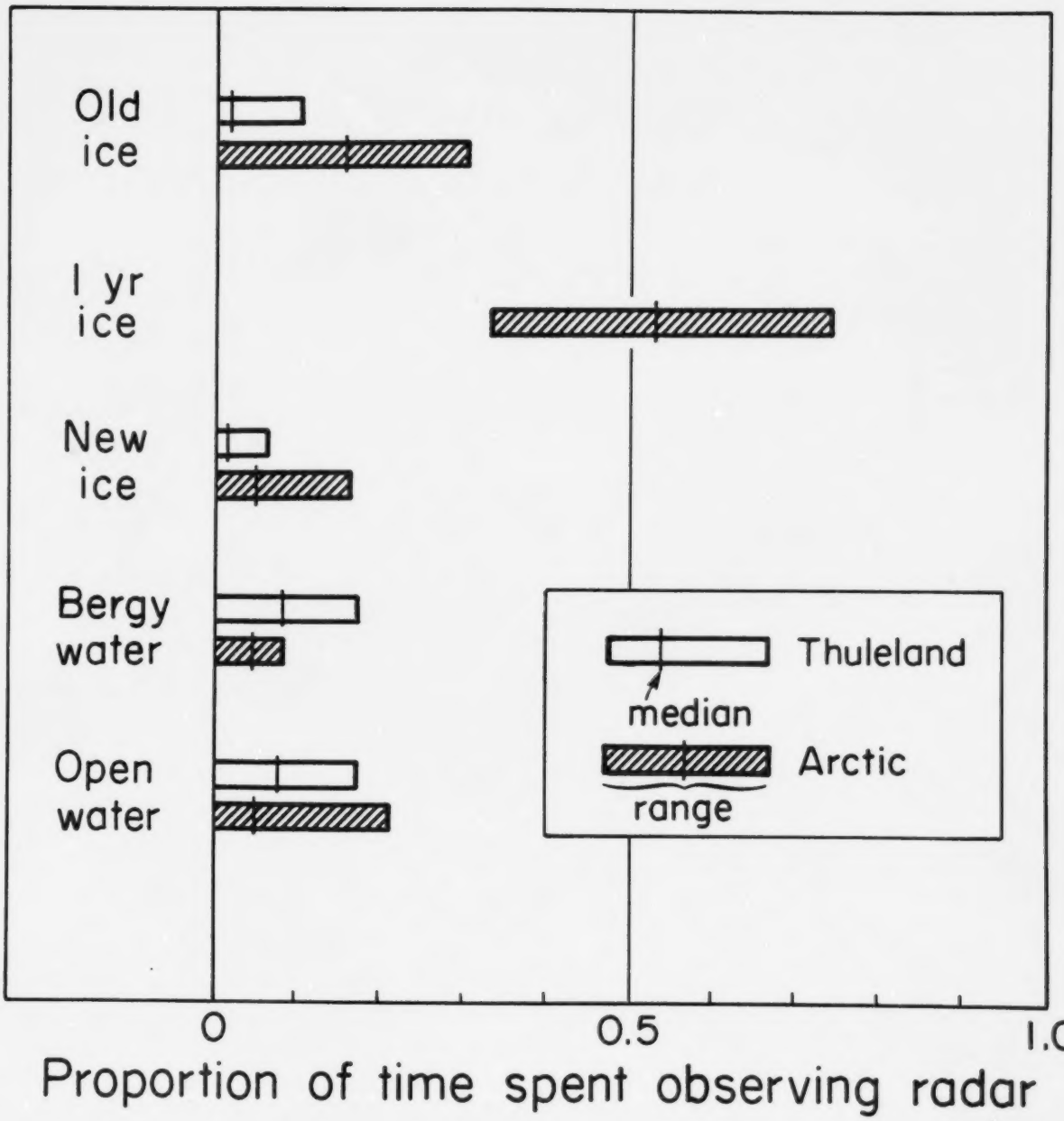

Figure 7 Proportion of time spent in radar observation in different ice conditions, all officers, M.V. Arctic and M.S. Thuleland

Figure 8. Number of visual observations per minute as a function of bridge crew size: M.V. Arctic and M.S. Thuleland

3.6 M.V. Canmar Kigoriak

3.6.1 Positions

By Officer. Table 18 indicates that all of the officers spent most of their time in the forward control position. The wing consoles were used only rarely: when manoeuvring directly alongside another ship, or alongside a dock or barge. It is also clear from Table 18 that little time was spent by any officer at the chart-table. This reflects the fact that little navigation activity took place aboard the Kigoriak.

Table 19 shows that the same high proportion of forward position use was maintained under day or night operation. No differences in position use were observed as a function of ice coverage.

Joint Positions. The Captain and First Mate jointly occupied the forward control console 56 percent of the time, while the Captain and the Second Mate jointly occupied this position 85 percent of the time. Since there was only one chair at this seated operator's position, the watch officer stood alongside the console on the outboard side, either to port or starboard of the centrally located operator's position which was between the two parallel control consoles. At night the second mate stood outboard of the starboard console, from which position he could help the captain by operating the searchlight directional controls in response to the ship's change in direction of movement or to the captain's spoken directions.

Stochastic modeling. Kigoriak officers tended to stay put--in the forward console or immediately adjacent locations. As a result, there were very few recorded transitions between positions. There were not enough to analyze the order of sequential dependencies in the transition matrices. The best prediction for the position of a Kigoriak officer is: seated in the forward console chair. This prediction would be accurate more than 80 percent of the time.

Table 18 Percent of Time Spent by Each Officer at Each Position, Summed Over all Episodes: Kigoriak

Officer	Position			
	Pt. Wing	Forward	St. Wing	Chart
Captain	3	94	2	1
First Mate	1	87	2	10
Second Mate	2	90	3	6

Note: The largest SD is 0.3 percent.

Table 19 Percent of Time Spent by Each Officer at Each Position in Day and Night Episodes: Kigoriak

Officer and Light	Position			
	Pt. Wing	Forward	Stbd. Wing	Chart
Captain: day	2	95	3	1
First Mate: day	1	90	3	6
Second Mate: day	2	91	2	5
Captain: night	3	96	1	1
First Mate: night	0	99	1	0
Second Mate: night	1	85	5	9

Note: The largest SD is 2 percent.

Table 20 Percent of Sampling Intervals for each Activity, Summed Over all Episodes: Kigoriak

Officer	Activity				
	Vision	Radar	Communication	Control	Navigation
Captain	20	10	21	76	0
First Mate	34	5	23	51	1
Second Mate	37	14	19	55	3

Note: The largest SD is 0.5 percent.

3.6.2 Activities

By Officer. The percent of visual activity recorded in Table 20 for all officers summed over all episodes is lower than recorded for visual activity on the other ships. This change is due to a change in the recording criterion. The officer in control of the ship - at the

forward control position - was almost continually engaged in visual activity. What is recorded in Table 18 and subsequent tables concerning the Kigoriak is a change in the orientation of visual activity: for example, a change from looking forward to looking abeam or astern. By the old criterion of recording, visual activity for the officer at the forward control position would be 99 or 100 percent minus the time spent looking at the radar, under all environmental conditions.

Another distinct feature of Kigoriak activity is the high proportion of communication and control activities. Because the ship is operated by tiller and thrust controls from a forward control console, one operator simultaneously manoeuvres the ship, maintains communications with other ships, helicopters and shore bases, and maintains intercom or direct voice communication with Kigoriak personnel and events. Table 21 indicates that the proportion of communication activities was higher at night. Most of the night task analysis data was obtained during an operation which required very close cooperation among the drillship, the other supply boats, and Kigoriak. The high communications frequency reflects the heavy demand of the processs by which a drillship's anchors are successively raised and released in order to free the drillship from the wellsite in response to ice pressure. Anchor handling episodes also resulted the high frequency of control process observed for the Captain and the second mate. During this operation, the Captain was operating the ship with the direct assistance of the second mate.

Table 21 Percent of Sampling Intervals for each Activity in Day and Night Episodes: Kigoriak

Officer and Light	Activity				
	Vision	Radar	Communication	Control	Navigation
Captain: day	25	10	17	77	0
First Mate: day	40	5	15	54	1
Second Mate: day	43	15	17	52	2
Captain: night	7	11	23	84	1
First Mate: night	0	13	41	50	2
Second Mate: night	13	12	18	63	12

Note: The largest SD is 7 percent.

Type of ice cover did not have a measurable effect on activity type or level.

Joint distribution. When the captain and the second mate were both on the bridge, they were engaged in simultaneous control activities on 61 percent of the sampling intervals. This high proportion of joint control activities reflects the cooperative nature of control under high workload conditions like those encountered when lifting drillship anchors at night. The captain operated the ship, while the second mate moved the searchlights and acted as a lookout.

Stochastic Modeling. The activity transition matrices are presented in Appendix D. All three Kigoriak officers: Captain, first and second mate -- demonstrated significant second or higher-order dependencies in transitions among activities ($p < .005$). The most frequent of these second-order sequences are presented in Table 22.

Table 22 M.V. Kigoriak: Most Frequent Second-Order Activities Sequences for Each Officer

Frequency rank	Officer		
	Captain	1st Mate	2nd Mate
1	M C M	V M V	V R V
2	M R M	M V M	V C V
3	C M C	M C M	R V R
4	R C R	C M C	M C M
5	V C V	V C V	C R C
6	C V C	V R V	C V C

Note: M=manoeuvring, C=communication, R=radar, V=visual observation

Note that for the captain and first mate, there is a tendency for communications, radar, and visual observation activities to be sandwiched between successive manual control activities. The second mate's activity patterns look more like those observed aboard the other ships: visual observations are the usual antecedent and sequel to other activities, like radar observation and communications. The difference in patterns for the captain and first mate reflects the frequency of continuous manual control aboard a supply boat, as opposed to the intermittent indirect control used aboard a transiting merchant ship.

Table 23 reports the mean duration of radar and communication events and the mean duration of the intervals between these events. Radar "looks" were shorter aboard Kigoriak than aboard the other two ships. The inter-event times were about the same. The purpose of radar aboard Kigoriak is primarily to provide range information.

Table 23 Mean Activity Length (AL) and Mean Inter-Activity Interval (IA) for Radar, Communication and Navigation. (Seconds): Kigoriak

Officer	Activity					
	Radar		Communication		Navigation	
	AL	IA	AL	IA	AL	IA
Captain	21	213	37	375	-	-
First Mate	18	422	30	464	-	-
Second Mate	25	401	25	742	-	-

4. DISCUSSION

The first goal was to establish a database of bridge crew activities and movements that occur in Arctic navigation. The second goal was to apply stochastic modeling techniques to the data to describe the sequence and order of these activities and movements. Stochastic modeling provides a quantitative basis for recommended changes to bridge design, training practices and manning of ships operating in Arctic waters.

A database was developed by coding the shipboard activities to conform with the file structure conventions of the SPSS^X language. This provides access to the data management and statistics packages available in SPSS^X without the associated costs of developing a special purpose language. Furthermore, the general accessibility of the SPSS^X system in Canada makes this record of operator performance in Arctic navigation available to users throughout the country.

In the report we describe organization of the database and how it can be accessed. We present figures, tables and summary statistics to describe the frequency of occurrence of various events on each of the ships in the data base. We also describe the sequential properties of the activities and movements of the officers and report on the order of the transition matrices that were obtained. These findings were presented in detail in Section 3 and are summarized below.

The statistical analysis of activities and movements show that radar use, communications, and manoeuvring are linked to visual observation in repetitive sequences

All other major types of bridge activity are linked to visual observation. In general, the linkage is ordered and systematic in senior officers, systematic but less ordered among watch officers, but occasionally not ordered at all. All of the zero-order (unordered) sequences occurred on one ship, among watchkeeping officers. Differences in workload, experience, watchkeeping expectations probably lead to the observed differences in the amount of order found in watchkeeping positions and activities.

There are differences between bridge crews in the total number of visual observations made per unit time as a function of the size of the crew on the bridge

Although officers alone on watch spent comparable amounts of time in visual observation aboard both the M.V. Arctic and the M.S. Thuleland, the rate at which visual observations increased as watch crew was added was different in the two ships. Observations aboard the M.V. Arctic replicate an earlier claim (Herrman, 1977) that total visual observations may decrease as the number of bridge crew increases (Figure 8). Differences in ship type, watchkeeping routine and operator workload may account for the observed differences in visual observation functions.

Watchkeeping routines, resulting from training or from established watchkeeping practices, obviously modify the effectiveness of bridge personnel in maintaining a high level of visual observation. We suspect that the frequency of visual observation is primarily a function of the real or perceived cost of ice impacts. This will vary with differences in ship types and ice concentrations.

The time spent at navigation tasks is inversely related to the time spent making visual observations

It is obvious that officers whose duties require that they spend time logging and plotting a course cannot spend the same time keeping a lookout. It is instructive to note, however, that for each officer the same relationship holds: the more time spent behind the chart table, the less time spent in visual observation. The proportion of time spent behind the chart table is large (thirteen to fifty-six percent, with a median of 24 percent across all officers studied.) This is a strong justification for making sure that forward visibility is possible from the chart table, and for reducing as much as possible the time which watch officers are obliged to spend in charting and logging.

Radar and communications equipment are used frequently by all officers on all ships

Radars and communications equipment are used continually while officers are keeping watch. Since watchkeepers both need and want to stand near the forward windows, the equipment which they need most frequently should be placed near the forward windows, so they do not have to turn around, interfering with their visual observation, to find and use it. Efficient watchkeeping requires radars located close to the forward windows.

Operators stand near radars

Therefore, radars should be placed where it is appropriate for watchkeepers to stand -- behind the forward bulkhead, near the windows. This is especially true given the finding that experienced officers demonstrate a continual sequencing between vision and communications, or between vision and radar, and then back immeditely to vision.

The distributions of durations of radar use and communications are exponential

Of the three ships in the database, the durations of radar observations were shortest on the Kigoriak; the interval between successive communications was also shortest on the Kigoriak

Few systematic studies have been carried out on the distribution of activity durations in multi-task environments. However, it is assumed that these distributions are exponential in form (Wickens, 1984). This possibility was assessed in the present data examining

the pattern of means and standard deviations of distribution of durations for radar and communication acitivities. In exponential distributions, the means and standard deviations are equal.

For both the radar and communications data, activity durations were well accommodated by the exponential distribution. For radar, the correlation between the sample means and standard deviations accounted for 68 % of the variance in radar looking time. For communication durations, the correlation between the sample means and standard deviations accounted for 87 % of the variance in communcations durations.

Thus, for both radar and communications durations the correlations between means and standard deviations accounted for a substantial proportion of the variance in activity duration. This suggests that as in other multi-task environments, the exponential distribution readily accommodates the "sampling" or "service" periods for both of these shipboard activities in ice.

A process with an exponential duration distribution is one with no "memory". The probability that the process will stop is the same at every instant, and the decreased frequency of long durations reflects the cumulative effect of a constant probability of termination over the entire event. Thus, although the sequence of activities (e.g. from vision to radar to vision, or from vision to communication to vision) are predictable as a second or higher-order Markov chain for two out of three captains, and as a first-order chain for most other officers, the duration of a given activity is not predictable. The duration is random. Although this may indicate that the operator is not sensitive to differences in the information load, it may equally reflect an appropriate response to a randomly changing environmental information level.

The shorter inter-activity intervals aboard Kigoriak reflect a higher workload imposed on the conning officer who at the same time steers the ship, controls the thrust, and communicates both with other ships and within the ship, all of this while manoeuvring at close quarters. The inter-activity intervals and total movement and activity frequencies directly measure the workload on the bridge crew member. This workload is particularly high on a manoeuvering supply boat. The activity frequency as measured by this or similar task analysis techniques establishes a measure of workload which will be useful in studies of manning levels.

Officers on the Kigoriak frequently occupy nearby locations on the bridge; officers of the Arctic and Thuleland stand apart

Teamwork between the captain and mate of the Kigoriak was evident in controlling the lights during night operations while lifting the drillship anchors. Both officers worked alongside each other to share the total workload, although the Kigoriak bridge design was not efficient for two-man operations. This type of direct teamwork was not observed aboard either of the merchant ships.

4.1 Recommendations

The findings reviewed above lead us to make the following recommendations regarding bridge design and training for ships operating in ice-covered waters.

Communications equipment (VHF, intercom) and radar or radar repeaters should be available at all watchkeeping stations. The officers tend to stand near radars and use both communications and radar equipment frequently. Over all the data collected, the median radar observation lasts about 30 seconds and is repeated just over once every six minutes. The median communication lasts 25 seconds and is repeated about once every four minutes. Since the bridge wings are critical for visibility on a large ship with bridge aft, the absence of radar on the wings requires the operator either to walk from the bridge wing to the radar, which in the case of an emergency could result in a critical loss of time, or, alternatively, encourages the operator to choose non-optimal locations for watchkeeping in order to maintain proximity to radars.

The vertical height of the chart table should be low enough to allow visual observation from the navigating station. This is based on the finding that the amount of visual observation varies inversely with the amount of time spent at the navigating station. In effect, watchkeeping effort is traded for work at the chart table. Some watchkeeping effort could be maintained with a low vertical back on the chart table.

We encourage the development and use of automated logging and charting systems to enable watch officers to devote as much time as possible to the watchkeeping function. We found that 2nd and 3rd mates in some situations spend as much as 50% of their time at the chart table. The time spent at the chart table reduces the overall watchkeeping level.

The design and layout of the bridge and its manning must vary with the ship's functions and the location of the bridge. The data in this report must be interpreted correctly in this regard. The frequency of control actions by the Master on the Kigoriak was high in comparison to those of the Masters of the Arctic and the Thuleland. Since the accuracy of continuous control, such as employed on the Kigoriak, is greater than that of intermitent control, even in systems with long time constants and large inertia (Poulton, 1974), one might think that seated control from a one-person control station would optimize operator performance in ice piloting. Although we believe this to be true for supply boats such as the Kigoriak with its forward bridge and narrow beam, it is inappropriate for transiting cargo carriers. The length of the Arctic and the Thuleland in combination with the after position of their bridges and placement of the crane towers obstructs large portions of the visual field. Continuous control from a single seated bridge position appears to be inappropriate for these ships.

Millar and Hansford (1983) reported that in open water there is a tendency for watchkeeping officers to cycle from visual observation to radar to chart table and back to visual observation. However we did not observe a single consistent cycle involving radar, chart, and

vision; instead, we observed that radar, navigation and communications activities were each preceded and followed by visual observations. The sequential patterns of activity and movement observed aboard three ships in this study confirm the importance of continuous access to visual observation along with all other types of activity. The implication of this finding for bridge design is that the equipment necessary for radar observation, navigation, communication and control should allow immediate access to visual observation. If the bridge crew is to allocate their effort in proportion to the information available at various locations and points in time, the officers must be free to use information as it is available and needed. Accordingly, we recommend that in training, emphasis not be placed on systematizing the order of activities on the bridge. Instead, we recommend that bridge design take account of the need for radar and communications equipment at piloting stations where there is good visibility.

Increased manning in ice will only increase watchkeeping efficency if established routines require regular visual observation on the part of all of the bridge crew. We encourage the development of a watchkeeping routine which makes optimum use of the additional pairs of eyes added by increased manning in ice. Otherwise, as Figure 8 suggests, the extra personnel may not be cost-effective in improving ice hazard avoidance. The importance of keeping a good watch -- of vigilant observation -- should be stressed in bridge crew training for ice operations, in order to maximize the probability of detecting and avoiding ice hazards.

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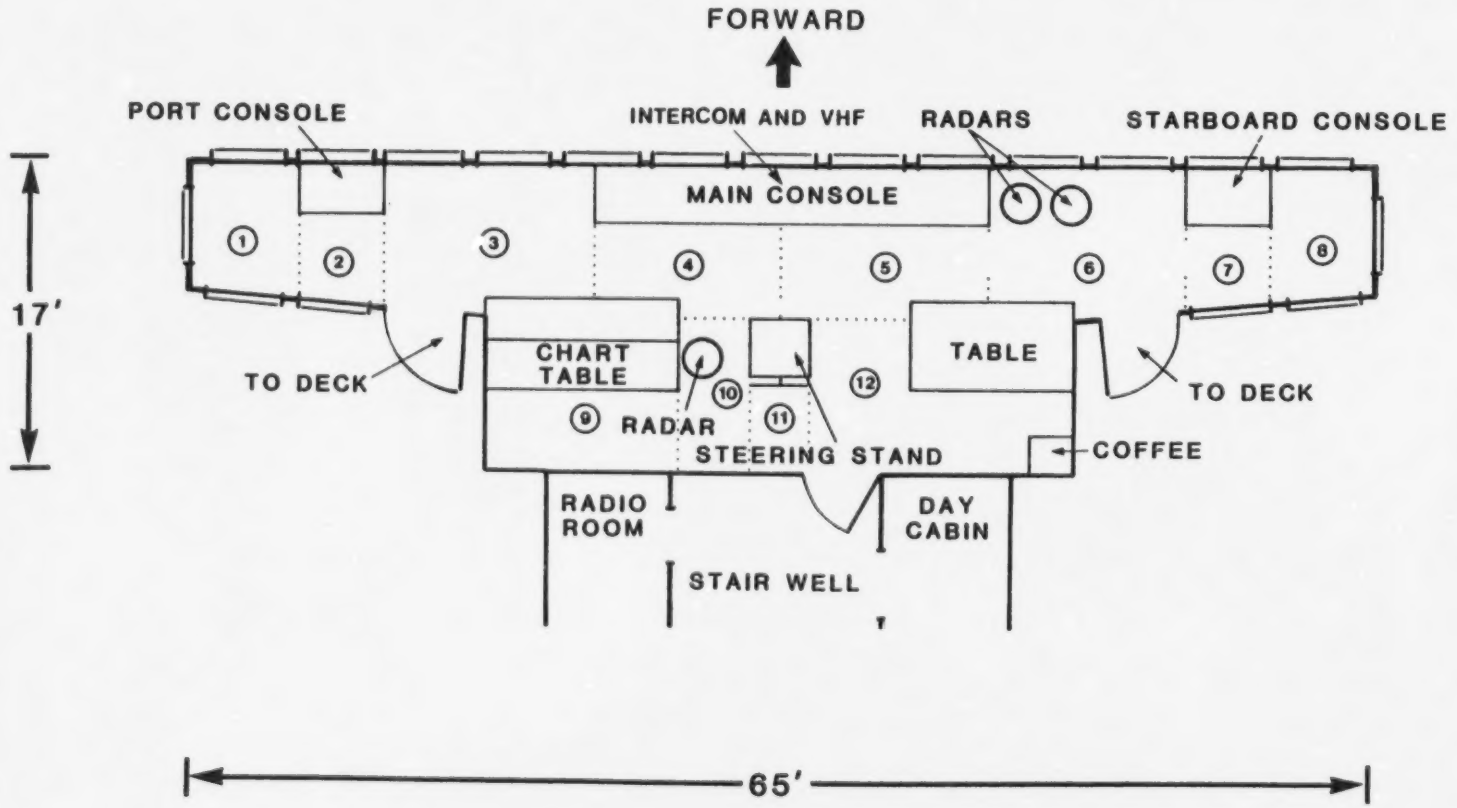
Appendix A Schematic Bridge Layouts for M.V. Arctic, M.S. Thuleland and M.V. Canmar Kigoriak

The bridge areas defined in these illustrations were condensed for purposes of statistical analysis. Table A.1 describes the condensation used to establish the bridge areas for analysis. Entries in the table are the numbered bridge regions which were condensed into each of the categories appearing at the side of the table.

Table A.1 Bridge Areas Defined for Statistical Analysis.

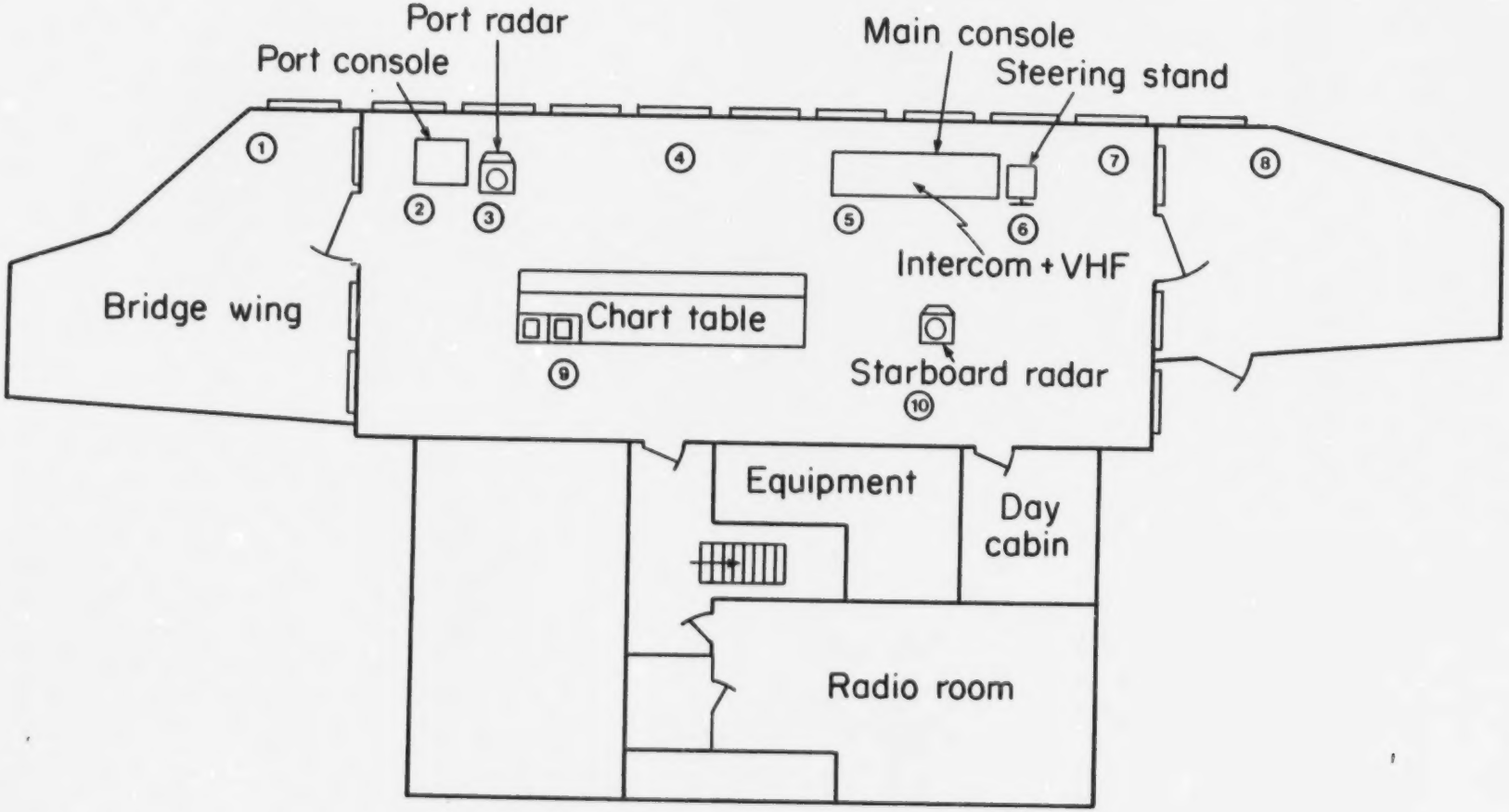
Ship	Condensed area	Numbered regions included in condensed area
Arctic	port wing	1,2,3
	main console	4,5
	starboard wing	6,7,8
	chart table	9,10,11,12
Thuleland	port wing	2,3,4
	starboard wing	5,6,7
	chart table	9
	starboard radar	10
Kigoriak	port console	1,2,4
	forward console	5,6,7
	starboard console	8,9,10
	chart table	3

BRIDGE OF M.V. ARCTIC, JUNE–JULY 1983

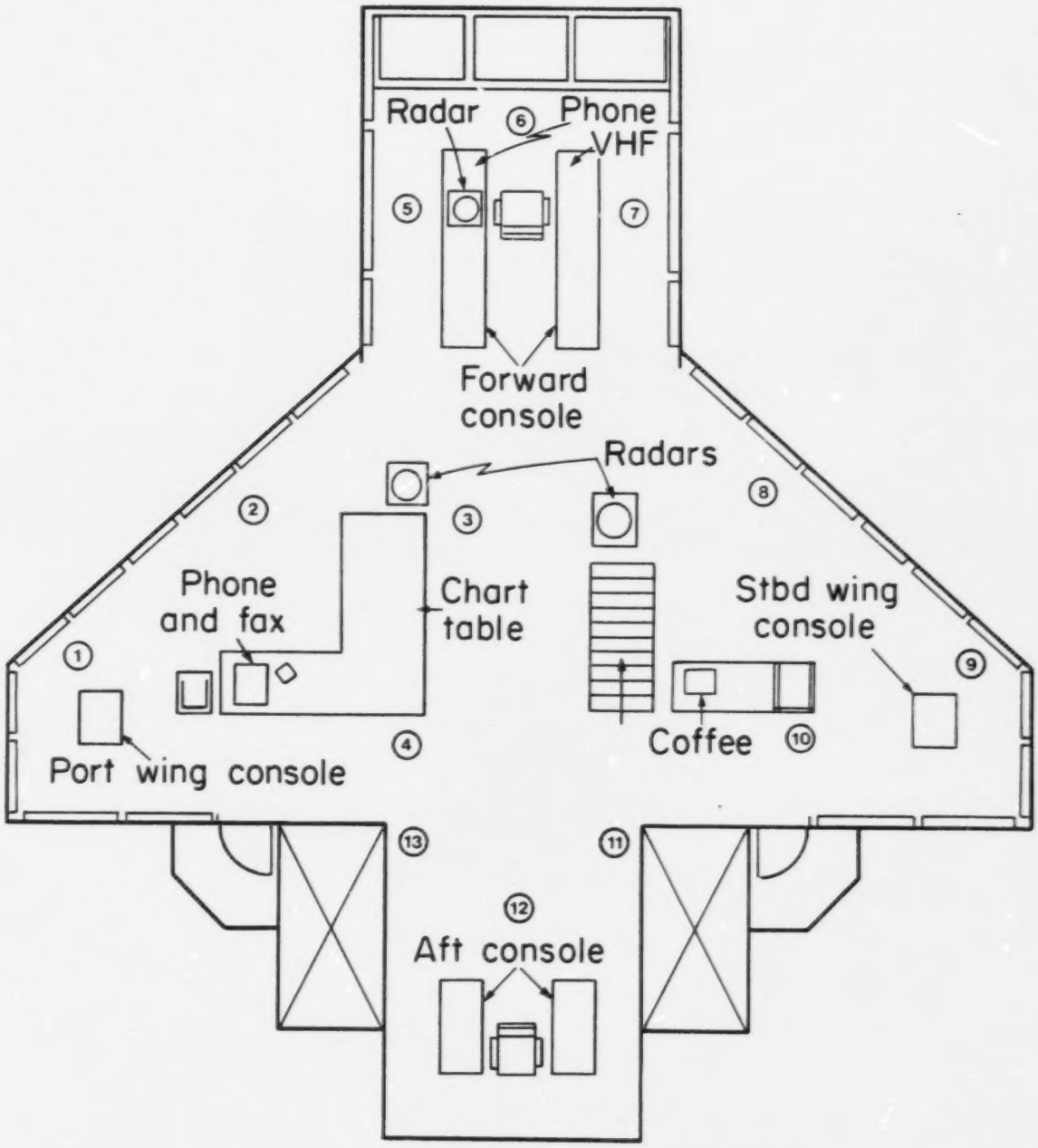


NUMBERS LOCATE OFFICER'S POSITIONS DURING POSITION AND MOVEMENT ANALYSIS

Bridge of M.S. Thuleland, September 1984



Bridge of M.V. Canmar Kigoriak, October 1984



APPENDIX B

Table B.1 DATA Codebook: Record Type 1

Variable Name	Description	Columns
RECTYPE	Record type: details in text	1-3
FILEID	File identification code	6-13
	6 = ship codebook ID (see table 6) 7 = last digit of year 8-9 = month (01-12) 10-11 = day (01-31) 12-13 = episode number (01-99)	
NREC	Number of records in episode	16-19
LAT	Latitude of ship	21-25
	21-22 = degrees 23-24 = minutes 25 = N or S	
LONG	Longitude of ship	26-30
	26-27 = degrees 28-29 = minutes 30 = E or W	
COURSE	True bearing (degrees)	31-33
SPEED	Ship's speed in knots	36-38
LTIME	Local time (hours and minutes)	41-45
GMT	Greenwich mean time (hours and minutes)	46-49
WINDSP	Windspeed in kilometers/hour	51-53
WINDDIR	Wind direction (true bearing)	56-58
SEA	Sea State	61-63

Table B.1 (Cont'd)

ICEC	Ice coverage (fraction of 10: 5 = 5/10)	66-68
ICET	Ice type (71, type: N=new, F=first-year, O=old, B=bergy water, W=open water; 72-75, modifiers: SN=snow, RI=ridged, RA=rafted, HU=Hummocks, MP=melt pools, RU=rubble)	71-75
RECNO	Record sequence number	76-79

Table B.2 DATA Codebook: Record Type 2

Variable Name	Description	Columns
RECTYPE	Record type: see text	1-3
ID1	Codebook identifier for person 1 (see table 6)	6-8
ID2	Codebook identifier for person 2	11-13
ID3	Codebook identifier for person 3	16-18
ID4	Codebook identifier for person 4	21-23
ID5	Codebook identifier fo rperson 5	26-28
ID6	Codebook identifier for person 6	31-33
VIS	Visibility in Meters	36-40
RECNO	Record sequence number	76-79

Table B.3 DATA Codebook: Record Type 3

Variable Name	Description	Columns
RECTYPE	Record type	1-3
SEQNO	Sample sequence number	6-8
P1	Position of the first person	11-13
A11	First person - first activity	16-18
A12	First person - second activity	21-23
A13	First person - third activity	26-28
P2	Position of the second person	31-33
A21	Second person - first activity	36-38
A22	Second person - second activity	41-43
A23	Second person - third activity	46-48
P3	Position of the third person	51-53
A31	Third person - first activity	56-58
A32	Third person - second activity	61-63
A33	Third person - third activity	66-68
RECNO	Record sequence number	76-79

Table B.4 DATA Codebook: Record type 4

Variable Name	Description	Columns
RECTYPE	Record type	1-3
SEQNO	Task sample sequence number	6-8
P4	Position of the fourth person	11-13
A41	Fourth person - first activity	16-18
A42	Fourth person - second activity	21-23
A43	Fourth person - third activity	26-28
P5	Position of the fifth person	31-33
A51	Fifth person - first activity	36-38
A52	Fifth person - second activity	41-43
A53	Fifth person - third activity	46-48
P6	Position of the sixth person	51-53
A61	Sixth person - first activity	56-58
A62	Sixth person - second activity	61-63
A63	Sixth person - third activity	66-68
RECNO	Record sequence number	76-79

Table B.5 DATA Codebook: Record type 5

Variable Name	Description	Columns
RECTYPE	Record type	1-3
COMMENT	Unrestricted entry of character data: comments continued on adjacent cards	6-70
RECNO	Record sequence number	76-79

Table B.6 Ship and Personnel Identifiers

Person identifier	Ship and ship identifier		
	M.V. Arctic	M.S. Thuleland	M.V. Canmar Kigoriak
1	Captain	Captain	Captain
2	Reserve captain	First mate	First mate
3	First mate	Second mate	Second mate
4	Second mate	Third mate	Reserve captain
5	Third mate	Reserve captain 1	-
6	Ice observer 1	Reserve captain 2	-
7	Ice observer 2	Helmsman	-
8	Helmsman	-	-
9	Ice observer 3	-	-

Table B.7 Coding for Transformed Variables

Meaning	DATA file equivalents	Numerical code
Aft windows (activity)	AFT, __A	21
Beam windows (activity)	BEA	22
Binoculars (activity)	BIN, __B	23
Bow radar (activity)	BRA, _RB	25
Chart table (activity)	CHA, __C	50
Forward windows (activity)	FOR, __F	20
Lights (activity)	LIG, __S	70
Off bridge (position)	OFF	17
Off-ship (activity)	__O	34
Phone (activity)	PHO	35
Radar (activity)	RAD, __R	24
Transit (position)	TRA, __T	16
Voice (activity)	VOI, __V	33
Walkie-talkie (activity)	_WT	37

Table B.8 Equivalent Character and Numerical Variables

Character	Numerical	Character	Numerical
P1	NTR1	P4	NTR13
A11	NTR2	A41	NTR14
A12	NTR3	A42	NTR15
A13	NTR4	A43	NTR16
P2	NTR5	P5	NTR17
A21	NTR6	A51	NTR18
A22	NTR7	A52	NTR19
A23	NTR8	A53	NTR20
P3	NTR9	P6	NTR21
A31	NTR10	A61	NTR22
A32	NTR11	A62	NTR23
A33	NTR12	A63	NTR24

Appendix C Program Listings and Sample Outputs

Appendix C.1 Position Sequence Analysis

```
/INFO  MVS  MSGLEVEL(1) CL(32) TI(75) PA(9999)  R(MUSIC)
// EXEC SPSSX
//IN DD DSN=#MCH.KIGOR3,DISP=SHR
//FIN DD DSN=#MCH.KPSEQ18,DISP=OLD
COMMENT
COMMENT    NOTE TO FILL IN AND CHANGE FIN FILE NAME ON EACH EXECUTION.
COMMENT
TITLE     POSITION SEQUENCE ANALYSIS: KIGORIAK 2ND MATE
GET FILE=IN
COMMENT  SPSS FILE TO ESTABLISH THE LENGTH AND NUMBER OF POSITION
  SEQUENCES FOR EACH PERSON.  THIS IS DONE BY ESTABLISHING A COUNT
  VARIABLE, #PX, WHICH KEEPS TRACK OF HOW MANY SUCCESSIVE ENTRIES
  THERE ARE IN EACH POSITION.  WHEN THE RECORDED POSITION CHANGES,
  THIS VARIABLE IS READ OUT (ON THE NEXT CASE) AS THE LENGTH OF A
  POSITION SEQUENCE.  THE POSITION NUMBER OF THE PREVIOUS CASE IS READ
  OUT AS THE POSITION VALUE FOR THAT SEQUENCE LENGTH.  THEN A FREQUENCY
  COUNT OF THE DIFFERENT VALUES IS OBTAINED, FOR BOTH THE LENGTH AND
  THE POSITION INDEX.  A TRANSITION MATRIX FOR ALL POSITIONS
  IS CALCULATED USING THE CROSSTABS PROCEDURE.  ONCE THE POSITION
  SEQUENCES HAVE BEEN SELECTED FOR LISTING AND PRINTING, A TRANSISION
  MATRIX WITH EMPTY DIAGONALS IS CALCULATED FOR TRANSITIONS BETWEEN
  DIFFERENT POSITIONS, EXCLUDING SUCCESSIVE SAMPLING INTERVALS IN WHICH
  THE SAME POSITION IS OCCUPIED.
RECODE ID1 TO ID6 (20,30=1) (21,31=2) (22,32=3) (23,33=4)
                  (24,34=5) (25,35=6) (26,36=7) (27,37=8)
                  (28,38=8) (29,39=9)
RECODE NTR1, NTR5, NTR9, NTR13, NTR17, NTR21 (1,2,4=1)/* K POSITION
   (5,6,7 = 2) (8,9,10=3)  (3=4) (ELSE = SYSMIS) /* K POSITION RECODE
VALUE LABELS NTR1, NTR5, NTR9, NTR13, NTR17, NTR21  1 'PORT WING'
   2 'FORWARD'  3 'STBD WING'  4 'CHART AND RADAR' /* K VALUE LABELS
VARIABLE LABELS  NTR1 'POSN PER1' NTR5 'POSN PER2'  NTR9'POSN PER3'
   NTR13 'POSN PER4'  NTR17 'POSN PER5'  NTR21 'POSN PER6'
RECODE NTR2,NTR3,NTR4,NTR6,NTR7,NTR8,NTR10,NTR11,NTR12,NTR14,NTR15,
   NTR16,NTR18,NTR19,NTR20,NTR22,NTR23,NTR24 (20,21,22,23= 1)
   (24=2) (33,34,35=3) (40,41,42,70,71=4) (50=5)
   (ELSE=SYSMIS)  /* K ACT RCD
VALUE LABELS NTR2,NTR3,NTR4,NTR6,NTR7,NTR8,NTR10,NTR11,
    NTR12,NTR14,NTR15,NTR16,NTR18,NTR19,NTR20,NTR22,NTR23,NTR24
    1 'VISION'  2 'RADAR'  3 'COMMUNICATION'
    4 'CONTROL'  5 'CHART AND LOG'/* ACT V LABEL
VECTOR POSN (20)
COMPUTE POSN(ID1) = NTR1
IF (SYSMIS(ID2)=0 AND MISSING(ID2)=0)  POSN(ID2) = NTR5
IF (SYSMIS(ID3)=0 AND MISSING(ID3)=0)  POSN(ID3) = NTR9
IF (SYSMIS(ID4)=0 AND MISSING(ID4)=0)  POSN(ID4) = NTR13
IF (SYSMIS(ID5)=0 AND MISSING(ID5)=0)  POSN(ID5) = NTR17
IF (SYSMIS(ID6)=0 AND MISSING(ID6)=0)  POSN(ID6) = NTR21
NUMERIC #PX, PIX, POSX, PRINT, LOPSX, DATA
                  /*
COMPUTE NPERS = 3  /* THIS VALUE CHANGES FOR A CHANGE IN THE PERSON.
                  /* ITS RANGE IS 1 - 9. LARGER VALUES DEFINED FOR
                  /* THE KIGORIAK AND THULELAND FILES ARE RECODED
                  /* TO THIS RANGE. VERIFY THE INDIVIDUAL IN THESE
                  /* FILES BE REFERRING TO THE RECODE STATEMENT.
                  /*
COMPUTE DATA = 18  /* THIS ARBITRARY VALUE CAN BE USED TO IDENTIFY
                  /* THE DATA FOR A PARTICULAR ANALYSIS. IT IS PRINTED
                  /* AS THE FIRST VARIABLE ON THE OUTPUT FILE AND IN
```

```
                    /* THE PRINTED OUTPUT.
                    /*
COMPUTE POSX = POSN(NPERS)
COMPUTE LPOSX = LAG(POSX,1)
DO IF (POSX EQ LPOSX)
+    COMPUTE  #PX = #PX + 1
+    COMPUTE PRINT = 0
ELSE
+    COMPUTE PX = LAG(#PX,1)
+    COMPUTE PIX = LPOSX
+    COMPUTE #PX = 1
+    COMPUTE PRINT = 1
END IF
CROSSTABS TABLES = LPOSX BY POSX
OPTION 14
STATISTIC 1
SELECT IF (PRINT = 1)
PRINT OUTFILE=FIN / DATA SHIP IDNUM NPERS SEQNO PIX PX
          /*
          /*  THIS NEXT CROSSTABS OUTPUT LISTS THE TRANSITION
          /*  FREQUENCIES AND PROBABILITIES BETWEEN DIFFERENT
          /*  POSITIONS, EXCLUDING ALL
          /*  TRANSITIONS BETWEEN THE SAME POSITION ON SUCCESSIVE
          /*  SAMPLING INTERVALS.
          /*
CROSSTABS TABLES = LPOSX BY POSX
OPTION 14
STATISTIC 1
FINISH
```

CROSSTABULATION OF LPOSX BY POSX

LPOSX	COUNT / EXP VAL	POSX 1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	ROW TOTAL
1.00		92	3	20	2	0	2	1	0	0	0	134
		11.7	2.6	18.0	4.0	10.0	15.5	1.6	6.0	33.5	.1	8.9%
2.00		6	13	7	0	0	0	0	0	0	0	28
		2.4	.5	3.8	.8	2.1	3.2	.3	1.3	7.0	.0	1.9%
3.00		13	7	118	4	9	6	1	4	11	0	204
		17.8	3.9	27.3	6.1	15.2	23.7	2.4	9.1	51.0	.1	13.6%
4.00		1	0	5	24	0	4	0	1	4	0	42
		3.7	.8	5.6	1.3	3.1	4.9	.5	1.9	10.5	.0	2.8%
5.00		2	0	7	0	68	7	0	3	13	0	109
		9.5	2.1	14.6	3.3	8.1	12.6	1.3	4.9	27.3	.1	7.3%
6.00		3	0	4	1	11	97	2	16	9	0	173
		15.1	3.3	23.2	5.2	12.9	20.1	2.1	7.7	43.3	.1	11.5%
7.00		0	1	0	2	0	2	5	3	2	0	18
		1.6	.3	2.4	.5	1.3	2.1	.2	.8	4.5	.0	1.2%
8.00		0	0	1	1	3	14	4	25	3	0	67
		5.9	1.3	9.0	2.0	5.0	7.8	.8	3.0	16.8	.0	4.5%
9.00		0	1	13	4	15	13	3	2	298	0	380
		33.2	7.3	50.9	11.4	28.4	44.1	4.6	17.0	95.0	.3	25.3%
10.00		0	0	0	0	0	0	0	0	0	0	1
		.1	.0	.1	.0	.1	.1	.0	.0	.3	.0	.1%
11.00		0	0	0	0	0	2	0	0	0	0	2
		.2	.0	.3	.1	.1	.2	.0	.1	.5	.0	.1%
12.00		0	0	0	0	0	1	0	0	0	0	4
		.3	.1	.5	.1	.3	.5	.0	.2	1.0	.0	.3%
16.00		14	4	26	7	6	24	2	13	34	1	182
		15.9	3.5	24.4	5.5	13.6	21.1	2.2	8.1	45.5	.1	12.1%
(CONTINUED)	COLUMN TOTAL	131 8.7%	29 1.9%	201 13.4%	45 3.0%	112 7.5%	174 11.6%	18 1.2%	67 4.5%	375 25.0%	1 .1%	1500 100.0%

CROSSTABULATION OF LPOSX BY POSX

LPOSX	COUNT / EXP VAL	POSX 11.00	POSX 12.00	POSX 16.00	POSX 850.00	ROW TOTAL
1.00		0	0	14	0	134
		.2	.4	16.3	14.1	8.9%
2.00		0	0	2	0	28
		.0	.1	3.4	2.9	1.9%
3.00		0	0	30	1	204
		.3	.5	24.9	21.5	13.6%
4.00		0	0	3	0	42
		.1	.1	5.1	4.4	2.8%
5.00		0	0	8	1	109
		.1	.3	13.3	11.5	7.3%
6.00		1	1	28	0	173
		.2	.5	21.1	18.2	11.5%
7.00		0	0	3	0	18
		.0	.0	2.2	1.9	1.2%
8.00		1	1	14	0	67
		.1	.2	8.2	7.1	4.5%
9.00		0	0	30	1	380
		.5	1.0	46.4	40.0	25.3%
10.00		0	1	0	0	1
		.0	.0	.1	.1	.1%
11.00		0	0	0	0	2
		.0	.0	.2	.2	.1%
12.00		0	1	2	0	4
		.0	.0	.5	.4	.3%
16.00		0	0	48	3	182
		.2	.5	22.2	19.2	12.1%
	COLUMN TOTAL	2	4	183	158	1500
		.1%	.3%	12.2%	10.5%	100.0%

(CONTINUED)

	COUNT / EXP VAL	POSX	ROW TOTAL

LPOSX		1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	
	850.00	0	0	0	0	0	2	0	0	1	0	156
		13.6	3.0	20.9	4.7	11.6	18.1	1.9	7.0	39.0	.1	10.4%
	COLUMN TOTAL	131 8.7%	29 1.9%	201 13.4%	45 3.0%	112 7.5%	174 11.6%	18 1.2%	67 4.5%	375 25.0%	1 .1%	1500 100.0%

CROSSTABULATION OF LPOSX BY POSX

LPOSX	POSX 11.00	12.00	16.00	850.00	ROW TOTAL
850.00	0	0	1	152	156
	.2	.4	19.0	16.4	10.4%
COLUMN TOTAL	2 .1%	4 .3%	183 12.2%	158 10.5%	1500 100.0%

CHI-SQUARE	D.F.	SIGNIFICANCE	MIN E.F.	CELLS WITH E. F.< 5
5365.00367	169	0.0000	0.001	125 OF 196 (63.8%)

NUMBER OF MISSING OBSERVATIONS = 4088

PRECEDING TASK REQUIRED 2.00 SECONDS CPU TIME; 29.74 SECONDS ELAPSED.

```
  57  0          SELECT IF (PRINT = 1)
  58  0          LIST VARIABLES=DATA SHIP IDNUM NPERS SEQNO PIX PX
  59  0                    /*
  60  0                    /*  THIS NEXT CROSSTABS OUTPUT LISTS THE TRANSITION
  61  0                    /*  FREQUENCIES AND PROBABILITIES BETWEEN DIFFERENT
  62  0                    /*  POSITIONS, EXCLUDING ALL
  63  0                    /*  TRANSITIONS BETWEEN THE SAME POSITION ON SUCCESSIVE
  64  0                    /*  SAMPLING INTERVALS.
  65  0                    /*
THERE ARE    71864 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS    71864 BYTES.
     599 BYTES OF MEMORY REQUIRED FOR LIST PROCEDURE.
     368 BYTES HAVE ALREADY BEEN ACQUIRED.
     231 BYTES REMAIN TO BE ACQUIRED.
```


DATA SHIP	IDNUM	NPERS	SEQNO	PIX	PX
4.00 A	3070322	3.00	4	3.00	2.00
4.00 A	3070322	3.00	5	1.00	1.00

```
     4.00 A     3070322      3.00    6       3.00      1.00
     4.00 A     3070322      3.00    7     850.00      1.00
     4.00 A     3102640      3.00  104      16.00      1.00

     ---------------546 ADDITIONAL CASES--------------

     4.00 A     3102640      3.00  106       3.00      2.00
     4.00 A     3102640      3.00  108       6.00      2.00
     4.00 A     3102640      3.00  109      16.00      1.00
     4.00 A     3102640      3.00  110       3.00      1.00
     4.00 A     3102640      3.00  112       5.00      2.00
     4.00 A     3102640      3.00  114       3.00      2.00
     4.00 A     3102640      3.00  115      16.00      1.00
     4.00 A     3102640      3.00  117       3.00      2.00
-NUMBER OF CASES READ =      559    NUMBER OF CASES LISTED =      559
02 SEP 85    POSITION SEQUENCE ANALYSIS: LIST-ONLY VERSION                                    PAGE  19
22:11:37     MCGILL UNIVERSITY              AMDAHL 5801      MVS 3.8

PRECEDING TASK REQUIRED       0.79 SECONDS CPU TIME;      30.18 SECONDS ELAPSED.

  66  0          CROSSTABS TABLES = LPOSX BY POSX
  67  0          OPTION 14
  68  0          STATISTIC 1

THERE ARE    72384 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS    72384 BYTES.
 ***** GIVEN WORKSPACE ALLOWS FOR  2412 CELLS WITH     2 DIMENSIONS FOR CROSSTAB PROBLEM *****


02 SEP 85    POSITION SEQUENCE ANALYSIS: LIST-ONLY VERSION                                    PAGE  20
22:11:40     MCGILL UNIVERSITY              AMDAHL 5801      MVS 3.8

- - - - - - - - - - - - - - - - - - -  C R O S S T A B U L A T I O N  O F  - - - - - - - - - - - - - - - - - - -
    LPOSX                                          BY  POSX
  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -  PAGE  1 OF  4

                POSX
          COUNT  I
         EXP VAL I
                 I                                                                                          ROW
                 I   1.00I    2.00I    3.00I    4.00I    5.00I    6.00I    7.00I    8.00I    9.00I   10.00I  TOTAL
LPOSX    --------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
          1.00   I      0 I      3 I     20 I      2 I      0 I      2 I      1 I      0 I      0 I      0 I     42
                 I    2.9 I    1.2 I    6.2 I    1.6 I    3.3 I    5.8 I    1.0 I    3.2 I    5.8 I     .1 I   7.5%
                 +--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
          2.00   I      6 I      0 I      7 I      0 I      0 I      0 I      0 I      0 I      0 I      0 I     15
                 I    1.0 I     .4 I    2.2 I     .6 I    1.2 I    2.1 I     .3 I    1.1 I    2.1 I     .0 I   2.7%
                 +--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
          3.00   I     13 I      7 I      0 I      4 I      9 I      6 I      1 I      4 I     11 I      0 I     86
                 I    6.0 I    2.5 I   12.8 I    3.2 I    6.8 I   11.8 I    2.0 I    6.5 I   11.8 I     .2 I  15.4%
                 +--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
          4.00   I      1 I      0 I      5 I      0 I      0 I      4 I      0 I      1 I      4 I      0 I     18
                 I    1.3 I     .5 I    2.7 I     .7 I    1.4 I    2.5 I     .4 I    1.4 I    2.5 I     .0 I   3.2%
                 +--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
          5.00   I      2 I      0 I      7 I      0 I      0 I      7 I      0 I      3 I     13 I      0 I     41
                 I    2.9 I    1.2 I    6.1 I    1.5 I    3.2 I    5.6 I    1.0 I    3.1 I    5.6 I     .1 I   7.3%
                 +--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
          6.00   I      3 I      0 I      4 I      1 I     11 I      0 I      2 I     16 I      9 I      0 I     76
                 I    5.3 I    2.2 I   11.3 I    2.9 I    6.0 I   10.5 I    1.8 I    5.7 I   10.5 I     .1 I  13.6%
```

7.00	0	.9	1	.4	0	1.9	2	.5	0	1.0	2	1.8	0	.3	3	1.0	2	1.8	0	.0	13	2.3%				
8.00	0	2.9	0	1.2	1	6.2	1	1.6	3	3.3	14	5.8	4	1.0	0	3.2	3	5.8	0	.1	42	7.5%				
9.00	0	5.7	1	2.3	13	12.2	4	3.1	15	6.5	13	11.3	3	1.9	2	6.2	0	11.3	0	.1	82	14.7%				
10.00	0	.1	0	.0	0	.1	0	.0	0	.1	0	.1	0	.0	0	.1	0	.1	0	.0	1	.2%				
11.00	0	.1	0	.1	0	.3	0	.1	0	.2	2	.3	0	.0	0	.2	0	.3	0	.0	2	.4%				
12.00	0	.2	0	.1	0	.4	0	.1	0	.2	1	.4	0	.1	0	.2	0	.4	0	.0	3	.5%				
16.00	14	9.3	4	3.8	26	19.9	7	5.0	6	10.5	24	18.5	2	3.1	13	10.1	34	18.5	1	.2	134	24.0%				
COLUMN TOTAL	39	7.0%	16	2.9%	83	14.8%	21	3.8%	44	7.9%	77	13.8%	13	2.3%	42	7.5%	77	13.8%	1	.2%	559	100.0%				

LPOSX — CROSSTABULATION OF LPOSX BY POSX

LPOSX / COUNT / EXP VAL	POSX 11.00	POSX 12.00	POSX 16.00	POSX 850.00	ROW TOTAL
1.00	0	0	14	0	42
	.2	.2	10.1	.5	7.5%
2.00	0	0	2	0	15
	.1	.1	3.6	.2	2.7%
3.00	0	0	30	1	86
	.3	.5	20.8	.9	15.4%
4.00	0	0	3	0	18
	.1	.1	4.3	.2	3.2%
5.00	0	0	8	1	41
	.1	.2	9.9	.4	7.3%
6.00	1	1	28	0	76
	.3	.4	18.4	.8	13.6%
7.00	0	0	3	0	13
	.0	.1	3.1	.1	2.3%
8.00	1	1	14	0	42

	I	.2 I	.2 I	10.1 I	.5 I	7.5%
9.00	I	0 I	0 I	30 I	1 I	82
	I	.3 I	.4 I	19.8 I	.9 I	14.7%
10.00	I	0 I	1 I	0 I	0 I	1
	I	.0 I	.0 I	.2 I	.0 I	.2%
11.00	I	0 I	0 I	0 I	0 I	2
	I	.0 I	.0 I	.5 I	.0 I	.4%
12.00	I	0 I	0 I	2 I	0 I	3
	I	.0 I	.0 I	.7 I	.0 I	.5%
16.00	I	0 I	0 I	0 I	3 I	134
	I	.5 I	.7 I	32.4 I	1.4 I	24.0%
COLUMN TOTAL		2 .4%	3 .5%	135 24.2%	6 1.1%	559 100.0%

CROSSTABULATION OF LPOSX BY POSX

LPOSX / COUNT / EXP VAL	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	ROW TOTAL
850.00	0	0	0	0	0	2	0	0	1	0	4
	.3	.1	.6	.2	.3	.6	.1	.3	.6	.0	.7%
COLUMN TOTAL	39 7.0%	16 2.9%	83 14.8%	21 3.8%	44 7.9%	77 13.8%	13 2.3%	42 7.5%	77 13.8%	1 .2%	559 100.0%

CROSSTABULATION OF LPOSX BY POSX

LPOSX / COUNT / EXP VAL	11.00	12.00	16.00	850.00	ROW TOTAL
850.00	0	0	1	0	4
	.0	.0	1.0	.0	.7%
COLUMN TOTAL	2 .4%	3 .5%	135 24.2%	6 1.1%	559 100.0%

CHI-SQUARE	D.F.	SIGNIFICANCE	MIN E.F.	CELLS WITH E.F.< 5
580.23155	169	0.0000	0.002	155 OF 196 (79.1%)

PRECEDING TASK REQUIRED 0.16 SECONDS CPU TIME; 2.81 SECONDS ELAPSED.

```
 69  0          FINISH
   69 COMMAND LINES READ.
    0 ERRORS DETECTED.
      END OF JOB.
```

Appendix C.2 Multiple Activity Analysis

```
/INFO  MVS  MSGLEVEL(2,1) TI(50) CL(42) R(MUSIC) JOB(#MCHMULT)
// EXEC SPSSX
//IN DD DSN=#MCH.THULE4,DISP=SHR
COMMENT ---> FILE=MODEL.85.MULTRESP
              ***  D. C. DONDERI  APRIL/85 ***
             **** REVISED BY BOB GRIMES  JULY/85****
  SPSS FILE TO AMALGAMATE DATA IN THE DIFFERENT ACTIVITY
  VARIABLES TO GIVE AN ACTIVITY RECORD WHICH IS SPECIFIC TO A GIVEN
  PERSON.  THE DATA THUS SPECIFIED IS THEN USED TO CREATE MULTIPLE
  RESPONSE FREQUENCY COUNTS AND TABULATIONS, AND ALSO TO PREPARE
  COUNTS OF NUMBER OF SEQUENCES AND DIFFERENT SEQUENCE LENGTHS FOR
  DIFFERENT ACTIVITIES. THIS VERSION FOR ALL THREE DATA FILES
TITLE  MULTIPLE RESPONSE: THULELAND ALL DATA
GET FILE=IN
RECODE ID1 TO ID6 ( 20,30=1) (21,31=2) (22,32=3) (23,33=4)
                  (24,34=5) (25,35=6) (26,36=7) (27,37=8)
                  (28,38=8) (29,39=9)
RECODE NTR1, NTR5, NTR9, NTR13, NTR17, NTR21 (2,3,4=1)/* THULE RECODE
   (5,6,7=2) (9=3) (10=4) (ELSE=SYSMIS) /* THULELAND POSITION RECODE
VALUE LABELS NTR1, NTR5, NTR9, NTR13, NTR17, NTR21  1 'PORT FWD'
   2 'STBD FWD'   3 'CHART'  4 'STBD RADAR' /* THULELAND VALUE LABELS
VARIABLE LABELS  NTR1 'POSN PER1' NTR5 'POSN PER2'  NTR9 'POSN PER3'
   NTR13 'POSN PER4'  NTR17 'POSN PER5'  NTR21 'POSN PER6'
RECODE NTR2,NTR3,NTR4,NTR6,NTR7,NTR8,NTR10,NTR11,NTR12,NTR14,NTR15,
   NTR16,NTR18,NTR19,NTR20,NTR22,NTR23,NTR24 (20,21,22,23,25 = 1)
   (24=2)  (30,31,32,33,34,35=3) (40,41=4) (50=5)
   (ELSE=SYSMIS) /* T ACT RCD
VALUE LABELS NTR2,NTR3,NTR4,NTR6,NTR7,NTR8,NTR10,NTR11,
    NTR12,NTR14,NTR15,NTR16,NTR18,NTR19,NTR20,NTR22,NTR23,NTR24
    1  VISION   2 'RADAR'  3 'COMMUNICATION'
    4 'CONTROL' 5 'NAVIGATION'  /* ACT V LABEL
NUMERIC NICET
RECODE ICET ('W  '=1) ('B  '=2) ('N  '=3) ('F  '=4) ('O  '=5)
            (ELSE=SYSMIS) INTO NICET
VECTOR POSN, ACTI, ACTII, ACTIII (9)
COMPUTE POSN(ID1) = NTR1
IF (MISSING(ID2)=0)  POSN(ID2) = NTR5
IF (MISSING(ID3)=0)  POSN(ID3) = NTR9
IF (MISSING(ID4)=0)  POSN(ID4) = NTR13
IF (MISSING(ID5)=0)  POSN(ID5) = NTR17
IF (MISSING(ID6)=0)  POSN(ID6) = NTR21
COMPUTE ACTI(ID1) = NTR2
IF (MISSING(ID2)=0)  ACTI(ID2) = NTR6
IF (MISSING(ID3)=0)  ACTI(ID3) = NTR10
IF (MISSING(ID4)=0)  ACTI(ID4) = NTR14
IF (MISSING(ID5)=0)  ACTI(ID5) = NTR18
IF (MISSING(ID6)=0)  ACTI(ID6) = NTR22
COMPUTE ACTII(ID1) = NTR3
IF (MISSING(ID2)=0)  ACTII(ID2) = NTR7
IF (MISSING(ID3)=0)  ACTII(ID3) = NTR11
IF (MISSING(ID4)=0)  ACTII(ID4) = NTR15
IF (MISSING(ID5)=0)  ACTII(ID5) = NTR19
IF (MISSING(ID6)=0)  ACTII(ID6) = NTR23
COMPUTE ACTIII(ID1) = NTR4
IF (MISSING(ID2)=0)  ACTIII(ID2) = NTR8
IF (MISSING(ID3)=0)  ACTIII(ID3) = NTR12
IF (MISSING(ID4)=0)  ACTIII(ID4) = NTR16
IF (MISSING(ID5)=0)  ACTIII(ID5) = NTR20
```

```
IF (MISSING(ID6)=0)  ACTIII(ID6) = NTR24
MULT RESPONSE GROUPS PER1ACTS 'PER 1' ( ACTI1, ACTII1, ACTIII1 (1,99))
                     PER2ACTS 'PER 2' ( ACTI2, ACTII2, ACTIII2 (1,99) )
                     PER3ACTS 'PER 3' ( ACTI3, ACTII3, ACTIII3 (1,99) )
                     PER4ACTS 'PER 4' ( ACTI4, ACTII4, ACTIII4 (1,99) )
                     PER5ACTS 'PER 5' ( ACTI5, ACTII5, ACTIII5 (1,99) )
                     PER6ACTS 'PER 6' ( ACTI6, ACTII6, ACTIII6 (1,99) )
                     PER7ACTS 'PER 7' ( ACTI7, ACTII7, ACTIII7 (1,99) )
                     PER8ACTS 'PER 8' ( ACTI8, ACTII8, ACTIII8 (1,99) )
                     PER9ACTS 'PER 9' ( ACTI9, ACTII9, ACTIII9 (1,99) )
 /VARIABLES=IDNUM(1,9) POSN1,POSN2,POSN3,POSN4,
            POSN5,POSN6,POSN7,POSN8,POSN9 (1,99) NICET(1,5)
 /FREQUENCIES = PER1ACTS,PER2ACTS,PER3ACTS,PER4ACTS,PER5ACTS,PER6ACTS,
                PER7ACTS,PER8ACTS,PER9ACTS
                POSN1,POSN2,POSN3,POSN4,POSN5,POSN6,POSN7,POSN8,POSN9
 /TABLES = POSN1 TO POSN9 BY NICET / PER1ACTS TO PER9ACTS BY NICET
FINISH
```

GROUP PER1ACTS PER 1

CATEGORY LABEL	CODE	COUNT	PCT OF RESPONSES	PCT OF CASES
	1	529	73.5	90.1
	2	36	5.0	6.1
	3	63	8.8	10.7
	4	6	0.8	1.0
	5	86	11.9	14.7
TOTAL RESPONSES		720	100.0	122.7

1023 MISSING CASES 587 VALID CASES

GROUP PER2ACTS PER 2

CATEGORY LABEL	CODE	COUNT	PCT OF RESPONSES	PCT OF CASES
	1	391	66.6	88.7
	2	42	7.2	9.5
	3	68	11.6	15.4
	4	4	0.7	0.9
	5	82	14.0	18.6
TOTAL RESPONSES		587	100.0	133.1

1169 MISSING CASES 441 VALID CASES

GROUP PER3ACTS PER 3

CATEGORY LABEL	CODE	COUNT	PCT OF RESPONSES	PC T OF CASES
	1	194	45.8	53.4
	2	82	19.3	22.6
	3	50	11.8	13.8
	4	2	0.5	0.6
	5	96	22.6	26.4
TOTAL RESPONSES		424	100.0	116.8

1247 MISSING CASES 363 VALID CASES

GROUP PER4ACTS PER 4

CATEGORY LABEL	CODE	COUNT	PCT OF RESPONSES	PC T OF CASES
	1	603	67.9	92.9
	2	91	10.2	14.0
	3	68	7.7	10.5
	4	45	5.1	6.9
	5	81	9.1	12.5
TOTAL RESPONSES		888	100.0	136.8

961 MISSING CASES 649 VALID CASES

GROUP PER5ACTS PER 5

CATEGORY LABEL	CODE	COUNT	PCT OF RESPONSES	PCT OF CASES
	1	410	67.0	90.7
	2	72	11.8	15.9
	3	89	14.5	19.7
	4	13	2.1	2.9
	5	28	4.6	6.2
TOTAL RESPONSES		612	100.0	135.4

1158 MISSING CASES 452 VALID CASES

GROUP PER6ACTS PER 6

CATEGORY LABEL	CODE	COUNT	PCT OF RESPONSES	PCT OF CASES
	1	232	61.4	68.2
	2	30	7.9	8.8
	3	63	16.7	18.5
	4	3	0.8	0.9
	5	50	13.2	14.7
TOTAL RESPONSES		378	100.0	111.2

1270 MISSING CASES 340 VALID CASES

GROUP PER7ACTS PER 7

CATEGORY LABEL	CODE	COUNT	PCT OF RESPONSES	PCT OF CASES
	1	1478	91.9	121.3
	2	47	2.9	3.9
	3	54	3.4	4.4
	4	19	1.2	1.6
	5	11	0.7	0.9
TOTAL RESPONSES		1609	100.0	132.1

392 MISSING CASES 1218 VALID CASES

GROUP PER8ACTS PER 8

CATEGORY LABEL	CODE	COUNT	PCT OF RESPONSES	PCT OF CASES

-ALL CASES FOR THIS VARIABLE/GROUP WERE MISSING.

1610 MISSING CASES 0 VALID CASES

GROUP PER9ACTS PER 9

CATEGORY LABEL	CODE	COUNT	PCT OF RESPONSES	PCT OF CASES

-ALL CASES FOR THIS VARIABLE/GROUP WERE MISSING.

1610 MISSING CASES 0 VALID CASES

VARIABLE POSN1

CATEGORY LABEL	CODE	COUNT	PCT OF RESPONSES	PCT OF CASES
	1	269	42.0	42.0
	2	211	32.9	32.9
	3	126	19.7	19.7
	4	35	5.5	5.5
TOTAL RESPONSES		641	100.0	100.0

969 MISSING CASES 641 VALID CASES

VARIABLE POSN2

CATEGORY LABEL	CODE	COUNT	PCT OF RESPONSES	PCT OF CASES
	1	222	47.0	47.0
	2	105	22.2	22.2
	3	109	23.1	23.1
	4	36	7.6	7.6
TOTAL RESPONSES		472	100.0	100.0

1138 MISSING CASES 472 VALID CASES

VARIABLE POSN3

CATEGORY LABEL	CODE	COUNT	PCT OF RESPONSES	PCT OF CASES
	1	144	39.1	39.1
	2	14	3.8	3.8
	3	115	31.3	31.3
	4	95	25.8	25.8
TOTAL RESPONSES		368	100.0	100.0

1242 MISSING CASES 368 VALID CASES

VARIABLE POSN4

CATEGORY LABEL	CODE	COUNT	PCT OF RESPONSES	PCT OF CASES
	1	142	21.7	21.7
	2	329	50.3	50.3
	3	94	14.4	14.4
	4	89	13.6	13.6
TOTAL RESPONSES		654	100.0	100.0

956 MISSING CASES 654 VALID CASES

VARIABLE POSN5

CATEGORY LABEL	CODE	COUNT	PCT OF RESPONSES	PCT OF CASES
	1	175	38.2	38.2
	2	183	40.0	40.0
	3	47	10.3	10.3

```
                                        4          53       11.6       11.6
                                                -------    -----      -----
                                  TOTAL RESPONSES          458      100.0      100.0
    1152 MISSING CASES          458 VALID CASES
03 SEP 85    MULTIPLE RESPONSE: THULELAND ALL DATA                                    PAGE  17
 17:02:10    MCGILL UNIVERSITY                AMDAHL 5801      MVS 3.8

VARIABLE POSN6

 CATEGORY LABEL                                  CODE      COUNT  PCT OF  PC T OF
                                                                   RESPONSES  CASES
                                                    1        140      40.5       40.5
                                                    2         93      26.9       26.9
                                                    3         88      25.4       25.4
                                                    4         25       7.2        7.2
                                                -------    -----      -----
                                  TOTAL RESPONSES          346      100.0      100.0
    1264 MISSING CASES          346 VALID CASES
03 SEP 85    MULTIPLE RESPONSE: THULELAND ALL DATA                                    PAGE  18
17:02:10     MCGILL UNIVERSITY                AMDAHL 5801      MVS 3.8

 VARIABLE POSN7

 CATEGORY LABEL                                  CODE      COUNT  PCT OF  PCT OF
                                                                   RESPONSES  CASES
                                                    1        332      29.8       29.8
                                                    2        713      63.9       63.9
                                                    3         17       1.5        1.5
                                                    4         53       4.8        4.8
                                                -------    -----      -----
                                  TOTAL RESPONSES         1115      100.0      100.0
     495 MISSING CASES         1115 VALID CASES
03 SEP 85    MULTIPLE RESPONSE: THULELAND ALL DATA                                    PAGE  19
17:02:10     MCGILL UNIVERSITY                AMDAHL 5801      MVS 3.8

 VARIABLE POSN8

 CATEGORY LABEL                                  CODE      COUNT  PCT OF  PCT OF
                                                                   RESPONSES  CASES
-ALL CASES FOR THIS VARIABLE/GROUP WERE MISSING.
    1610 MISSING CASES            0 VALID CASES
03 SEP 85    MULTIPLE RESPONSE: THULELAND ALL DATA                                    PAGE  20
17:02:10     MCGILL UNIVERSITY                AMDAHL 5801      MVS 3.8

 VARIABLE POSN9

 CATEGORY LABEL                                  CODE      COUNT  PCT OF  PCT OF
                                                                   RESPONSES  CASES
-ALL CASES FOR THIS VARIABLE/GROUP WERE MISSING.
    1610 MISSING CASES            0 VALID CASES
03 SEP 85    MULTIPLE RESPONSE: THULELAND ALL DATA                                    PAGE  21
17:02:10     MCGILL UNIVERSITY                AMDAHL 5801      MVS 3.8

            * * *  C R O S S T A B U L A T I O N  * * *

    POSN1
 BY NICET

                    NICET
          COUNT     I
                    I                                    ROW
                    I                                    TOTAL
```

POSN1		1	2	3	5	
1		7	128	28	106	269
						42.0
2		1	80	59	71	211
						32.9
3		1	44	12	69	126
						19.7
4		0	20	6	9	35
						5.5
	COLUMN	9	272	105	255	641
	TOTAL	1.4	42.4	16.4	39.8	100.0

PERCENTS AND TOTALS BASED ON RESPONDENTS
641 VALID CASES 969 MISSING CASES

* * * C R O S S T A B U L A T I O N * * *

POSN2
BY NICET

POSN2	COUNT	NICET 2	NICET 5	ROW TOTAL
1		119	103	222
				47.0
2		64	41	105
				22.2
3		96	13	109
				23.1
4		29	7	36
				7.6
	COLUMN	308	164	472
	TOTAL	65.3	34.7	100.0

PERCENTS AND TOTALS BASED ON RESPONDENTS
472 VALID CASES 1138 MISSING CASES

* * * C R O S S T A B U L A T I O N * * *

POSN3
BY NICET

	COUNT	NICET

POSN3		1	2	5	ROW TOTAL
	1	12	128	4	144
					39.1
	2	1	13	0	14
					3.8
	3	83	32	0	115
					31.3
	4	44	51	0	95
					25.8
	COLUMN TOTAL	140 38.0	224 60.9	4 1.1	368 100.0

PERCENTS AND TOTALS BASED ON RESPONDENTS
368 VALID CASES 1242 MISSING CASES

* * * C R O S S T A B U L A T I O N * * *

POSN4
BY NICET

COUNT	POSN4	NICET 2	3	5	ROW TOTAL
	1	106	32	4	142
					21.7
	2	196	52	81	329
					50.3
	3	85	7	2	94
					14.4
	4	71	12	6	89
					13.6
	COLUMN TOTAL	458 70.0	103 15.7	93 14.2	654 100.0

PERCENTS AND TOTALS BASED ON RESPONDENTS
654 VALID CASES 956 MISSING CASES

* * * C R O S S T A B U L A T I O N * * *

POSN5
BY NICET

COUNT	NICET 2	NICET 5	ROW TOTAL
POSN5			
1	123	52	175
			38.2
2	83	100	183
			40.0
3	29	18	47
			10.3
4	29	24	53
			11.6
COLUMN TOTAL	264	194	458
	57.6	42.4	100.0

PERCENTS AND TOTALS BASED ON RESPONDENTS
458 VALID CASES 1152 MISSING CASES

* * * C R O S S T A B U L A T I O N * * *

POSN6
BY NICET

COUNT	NICET 1	NICET 2	NICET 5	ROW TOTAL
POSN6				
1	68	61	11	140
				40.5
2	4	25	64	93
				26.9
3	39	47	2	88
				25.4
4	16	9	0	25
				7.2
COLUMN TOTAL	127	142	77	346
	36.7	41.0	22.3	100.0

PERCENTS AND TOTALS BASED ON RESPONDENTS
346 VALID CASES 1264 MISSING CASES

* * * C R O S S T A B U L A T I O N * * *

POSN7

BY NICET

POSN7	COUNT	NICET 1	2	3	5	ROW TOTAL
	1	10	195	64	63	332
						29.8
	2	10	511	22	170	713
						63.9
	3	1	15	0	1	17
						1.5
	4	0	52	0	1	53
						4.8
	COLUMN TOTAL	21	773	86	235	1115
		1.9	69.3	7.7	21.1	100.0

PERCENTS AND TOTALS BASED ON RESPONDENTS
1115 VALID CASES 495 MISSING CASES

THE FOLLOWING TABLE IS COMPLETELY EMPTY..
POSN8 BY NICET

THE FOLLOWING TABLE IS COMPLETELY EMPTY..
POSN9 BY NICET

* * * C R O S S T A B U L A T I O N * * *

PER1ACTS (GROUP) PER 1
BY NICET

PER1ACTS	COUNT	NICET 1	2	3	5	ROW TOTAL
	1	5	247	88	189	529
						90.1
	2	0	28	1	7	36
						6.1
	3	0	48	2	13	63
						10.7
	4	1	2	0	3	6

		I	I	I	I	I 1.0
	5	I 0	I 27	I 10	I 49	I 86
		I	I	I	I	I 14.7
COLUMN		6	257	95	229	587
TOTAL		1.0	43.8	16.2	39.0	100.0

PERCENTS AND TOTALS BASED ON RESPONDENTS
587 VALID CASES 1023 MISSING CASES

* * * C R O S S T A B U L A T I O N * * *

PER2ACTS (GROUP) PER 2
BY NICET

COUNT	NICET 2	NICET 5	ROW TOTAL
PER2ACTS			
1	201	190	391
			88.7
2	25	17	42
			9.5
3	40	28	68
			15.4
4	3	1	4
			.9
5	70	12	82
			18.6
COLUMN	277	164	441
TOTAL	62.8	37.2	100.0

PERCENTS AND TOTALS BASED ON RESPONDENTS
441 VALID CASES 1169 MISSING CASES

* * * C R O S S T A B U L A T I O N * * *

PER3ACTS (GROUP) PER 3
BY NICET

COUNT	NICET 1	NICET 2	NICET 5	ROW TOTAL
PER3ACTS				
1	22	168	4	194
				53.4

2	24	58	0	82
				22.6
3	9	41	0	50
				13.8
4	1	1	0	2
				.6
5	71	25	0	96
				26.4
COLUMN TOTAL	125	234	4	363
	34.4	64.5	1.1	100.0

PERCENTS AND TOTALS BASED ON RESPONDENTS
363 VALID CASES 1247 MISSING CASES

* * * C R O S S T A B U L A T I O N * * *

PER4ACTS (GROUP) PER 4
BY NICET

PER4ACTS / COUNT	NICET 2	3	5	ROW TOTAL
1	390	105	108	603
				92.9
2	74	11	6	91
				14.0
3	60	3	5	68
				10.5
4	14	21	10	45
				6.9
5	74	6	1	81
				12.5
COLUMN TOTAL	456	101	92	649
	70.3	15.6	14.2	100.0

PERCENTS AND TOTALS BASED ON RESPONDENTS
649 VALID CASES 961 MISSING CASES

* * * C R O S S T A B U L A T I O N * * *

PER5ACTS (GROUP) PER 5
BY NICET

PER5ACTS	COUNT	NICET 2	NICET 5	ROW TOTAL
	1	225	185	410
				90.7
	2	51	21	72
				15.9
	3	50	39	89
				19.7
	4	3	10	13
				2.9
	5	11	17	28
				6.2
	COLUMN TOTAL	260 57.5	192 42.5	452 100.0

PERCENTS AND TOTALS BASED ON RESPONDENTS
452 VALID CASES 1158 MISSING CASES

* * * C R O S S T A B U L A T I O N * * *

PER6ACTS (GROUP) PER 6
BY NICET

PER6ACTS	COUNT	NICET 1	NICET 2	NICET 5	ROW TOTAL
	1	62	96	74	232
					68.2
	2	21	9	0	30
					8.8
	3	15	45	3	63
					18.5
	4	2	1	0	3
					.9
	5	31	17	2	50
					14.7
	COLUMN TOTAL	125 36.8	140 41.2	75 22.1	340 100.0

PERCENTS AND TOTALS BASED ON RESPONDENTS
340 VALID CASES 1270 MISSING CASES

* * * C R O S S T A B U L A T I O N * * *

PER7ACTS (GROUP) PER 7
BY NICET

COUNT	NICET 1	2	3	5	ROW TOTAL
PER7ACTS					
1	105	953	100	320	1478
					121.3
2	6	40	0	1	47
					3.9
3	2	35	1	16	54
					4.4
4	0	0	0	19	19
					1.6
5	0	11	0	0	11
					.9
COLUMN	108	777	85	248	1218
TOTAL	8.9	63.8	7.0	20.4	100.0

PERCENTS AND TOTALS BASED ON RESPONDENTS
1218 VALID CASES 392 MISSING CASES

THE FOLLOWING TABLE IS COMPLETELY EMPTY..
PER8ACTS BY NICET

THE FOLLOWING TABLE IS COMPLETELY EMPTY..
PER9ACTS BY NICET

PRECEDING TASK REQUIRED 1.80 SECONDS CPU TIME; 9.45 SECONDS ELAPSED.

```
 72  0          FINISH
  72 COMMAND LINES READ.
   0 ERRORS DETECTED.
   0 WARNINGS ISSUED.
   2 SECONDS CPU TIME.
  15 SECONDS ELAPSED TIME.
     END OF JOB.
```

Appendix C.3 Single Activity Sequence Analysis

SPSS INC LICENSE NUMBER: 783

NEW FEATURES IN SPSS-X RELEASE 2
FOR MORE DETAILS, USE THE COMMAND: INFO OVERVIEW FACILITIES.

PLOT - SCATTER PLOTS, OVERLAY PLOTS, CONTOUR PLOTS ON THE PRINTER.
HILOGLINEAR - FAST LOGLINEAR ANALYSIS FOR HIERARCHICAL MODELS.
CLUSTER - HIERARCHICAL CLUSTER ANALYSIS.
QUICK CLUSTER - FAST CLUSTER ANALYSIS FOR A FIXED NUMBER OF CLUSTERS.
IMPORT/EXPORT - PORTABLE SYSTEM FILES FOR TRANSFER TO OTHER KINDS OF COMPUTERS.
PROBIT - DICHOTOMOUS PROBIT AND LOGISTIC REGRESSION ANALYSIS.
LISREL - JORESKOG AND SORBOM'S PROGRAM FOR LINEAR STRUCTURAL RELATIONS.
(LISREL IS AN EXTRA-COST OPTION.)
SET WIDTH - WIDTH CONTROL FOR PRINTED OUTPUT.
XSAVE - ALLOWS NEW FLEXIBILITY IN SAVING SYSTEM FILES.
USERPROCS - YOU CAN ADD A PROCEDURE TO SPSS-X.
VSAM SUPPORT - SPSS-X CAN READ DATA FILES RESIDING IN VSAM DATA SPACES.
END SUBCOMMAND - WITH DATA LIST, YOU CAN DETECT END OF FILE.

```
  1  0          TITLE  SINGLE ACTIVITY SEQUENCES: COMMUN KIGOR OFFICERS
  2  0          COMMENT  SPSS FILE TO ESTABLISH THE LENGTH AND NUMBER OF ACTIVITY
  3  0            SEQUENCES FOR EACH PERSON.  THIS IS DONE BY FIRST COMBINING THE
  4  0            ACTIVITY RECORDS UNDER A SEPARATE VARIABLE VALUE FOR EACH PERSON
  5  0            ABOUT WHOM RECORDS HAVE BEEN KEPT.  THIS PART OF THE PROGRAM IS
  6  0            COMMON WITH THE BEGINNING OF THE MULTIPLE RESPONSE DATA PROGRAM.
  7  0            THEN THE INDIVIDUAL CASES ARE TESTED LOGICALLY FOR THE PRESENCE OF
  8  0            AN ACTIVITY OF A GIVEN KIND.  IF THE ACTIVITY IS PRESENT, AN INDEX
  9  0            IS STARTED WHICH COUNTS THE NUMBER OF SUCCESSIVE OCCURRENCES OF THAT
 10  0            ACTIVITY.  WHEN A SEQUENTIAL TIME RECORD OCCURS ON WHICH THE ACTIVITY
 11  0            IS NO LONGER RECORDED, THE INDEX OF SUCCESSIVE OCCURRENCES IS
 12  0            ENTERED ON THE RECORD FOR THAT CASE.  THE COMPLEMENT TO THIS IS
 13  0            ALSO RECORDED:  THE LENGTH OF THE RECORD SEQUENCES ON WHICH THE
 14  0            ACTIVITY IN QUESTION DID NOT OCCUR.  THE VARIABLE RECORDED FOR EACH
 15  0            CASE CAN THEN BE SUMMARIZED OR PRINTED OUT TO GIVE INFORMATION ABOUT
 16  0            THE STATISTICAL STRUCTURE OF ACTIVITY SEQUENCES.  THE VALUE OF THE
 17  0            VARIABLES IN QUESTION: FA OR XFA, IS RECORDED ONLY ON THE CASE
 18  0            IMMEDIATELY FOLLOWING THE END OF THE ACTIVITY OR NON-ACTIVITY
 19  0            SEQUENCE.  ALL OTHER ENTRIES FOR THESE VARIABLES ARE MISSING-VALUE
 20  0            ENTRIES.  THE SPECIFIC ACTIVITY IS REFERRED TO BY NUMBER: NACT.
 21  0            THE SPECIFIC PERSON IS REFERRED TO BY NUMBER: NPERS.
 22  0            THE VARIABLE WHICH RECORDS THE DURATION OF INTER-EVENT TIMES HAS
 23  0            BEEN TRUNCTUATED AT THE MAXIMUM DURATION OF THE EPISODE (NREC).
 24  0            THIS IS THE MAXIMUM DURATION EFFECTIVELY MEASURABLE GIVEN THE
 25  0            DATA.
 26  0          GET FILE=IN

FILE CALLED IN      :
  LABEL:
  CREATED 14 AUG 85 09:28:21      72 VARIABLES


 27  0          RECODE ID1 TO ID6 (20,30=1) (21,31=2) (22,32=3) (23,33=4)
 28  0                            (24,34=5) (25,35=6) (26,36=7) (27,37=8)
 29  0                            (28,38=8) (29,39=9)
```

```
  30  0          RECODE NTR2,NTR3,NTR4,NTR6,NTR7,NTR8,NTR10,NTR11,NTR12,NTR14,NTR15,
  31  0             NTR16,NTR18,NTR19,NTR20,NTR22,NTR23,NTR24 (34,35=34)
  32  0          VECTOR POSN, ACTI, ACTII, ACTIII (9)
  33  0          COMPUTE POSN(ID1) = NTR1
  34  0          IF (MISSING(ID2)=0)  POSN(ID2) = NTR5
  35  0          IF (MISSING(ID3)=0)  POSN(ID3) = NTR9
  36  0          IF (MISSING(ID4)=0)  POSN(ID4) = NTR13
  37  0          IF (MISSING(ID5)=0)  POSN(ID5) = NTR17
  38  0          IF (MISSING(ID6)=0)  POSN(ID6) = NTR21
  39  0          COMPUTE ACTI(ID1) = NTR2
  40  0          IF (MISSING(ID2)=0)  ACTI(ID2) = NTR6
  41  0          IF (MISSING(ID3)=0)  ACTI(ID3) = NTR10
  42  0          IF (MISSING(ID4)=0)  ACTI(ID4) = NTR14
  43  0          IF (MISSING(ID5)=0)  ACTI(ID5) = NTR18
  44  0          IF (MISSING(ID6)=0)  ACTI(ID6) = NTR22
  45  0          COMPUTE ACTII(ID1) = NTR3
  46  0          IF (MISSING(ID2)=0)  ACTII(ID2) = NTR7
  47  0          IF (MISSING(ID3)=0)  ACTII(ID3) = NTR11
  48  0          IF (MISSING(ID4)=0)  ACTII(ID4) = NTR15
  49  0          IF (MISSING(ID5)=0)  ACTII(ID5) = NTR19
  50  0          IF (MISSING(ID6)=0)  ACTII(ID6) = NTR23
  51  0          COMPUTE ACTIII(ID1) = NTR4
  52  0          IF (MISSING(ID2)=0)  ACTIII(ID2) = NTR8
  53  0          IF (MISSING(ID3)=0)  ACTIII(ID3) = NTR12
  54  0          IF (MISSING(ID4)=0)  ACTIII(ID4) = NTR16
  55  0          IF (MISSING(ID5)=0)  ACTIII(ID5) = NTR20
  56  0          IF (MISSING(ID6)=0)  ACTIII(ID6) = NTR24
  57  0          NUMERIC #AS, #XAS, AF, XAF, AIX, NACT, NPERS, PRINT, DATA
  58  0                               /*
  59  0          COMPUTE  DATA = 1  /* THIS VALUE REFERS TO A DATA DESCRIPTION
  60  0                             /* IN A DATA ANALYSIS LOG.
  61  0                             /*
  62  0          COMPUTE  NACT= 34 /* THIS VALUE CHANGES FOR A CHANGE IN THE ACTIVITY.
  63  0                             /* ITS RANGE IS ALL THE NUMBERED ACTIVITIES.
  64  0                             /*
  65  0          COMPUTE NPERS = 3  /* THIS VALUE CHANGES FOR A CHANGE IN THE PERSON.
  66  0                             /* ITS RANGE IS 1 - 7 (THE RECODED PERSON NUMBERS).
  67  0                             /*
  68  0          COMPUTE   AIX = 0  /* ZERO INDICATES THE ABSENCE OF THE ACTIVITY.
  69  0                             /* ONE INDICATES THAT THE ACTIVITY OCCURRED.
  70  0                             /*
  71  0          IF (ACTI(NPERS)=NACT OR ACTII(NPERS)=NACT OR ACTIII(NPERS)=NACT) AIX=1
  72  0          DO IF AIX = 1
  73  1          .   DO IF LAG(AIX,1)=1
  74  2          .      COMPUTE #AS = 1 + #AS
  75  2          .      COMPUTE #XAS = 0
  76  2          .      COMPUTE PRINT = 0
  77  2          .   ELSE
  78  2          .      COMPUTE #AS = 1
  79  2          .      COMPUTE XAF = #XAS
  80  2          .      COMPUTE PRINT = 1
  81  2          .   END IF
  82  1          ELSE
  83  1          .   DO IF LAG(AIX,1) = 1
```

```
 84  2          .      COMPUTE #XAS = 1
 85  2          .      COMPUTE AF = #AS
 86  2          .      COMPUTE PRINT = 1
 87  2          .   ELSE
 88  2          .      COMPUTE #AS = 0
 89  2          .      COMPUTE #XAS = 1 + #XAS
 90  2          .      COMPUTE PRINT = 0
 91  2          .   END IF
 92  1          END IF
 93  0          DO IF (#XAS GT NREC)
 94  1          .      COMPUTE #XAS = 0
 95  1          END IF
 96  0          FREQUENCIES VARIABLES= AF  XAF/
 97  0                      HISTOGRAM /
 98  0                      STATISTICS  DEFAULT VARIANCE MEDIAN SKEWNESS SESKEW

THERE ARE    65424 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS    65424 BYTES.

***** MEMORY ALLOWS A TOTAL OF   2973 VALUES, ACCUMULATED ACROSS ALL VARIABLES.
      THERE ALSO MAY BE UP TO    744 VALUE LABELS FOR EACH VARIABLE.
```

AF

VALUE LABEL	VALUE	FREQUENCY	PERCENT	VALID PERCENT	CUM PERCENT
	1.00	21	.8	67.7	67.7
	2.00	7	.3	22.6	90.3
	3.00	1	.0	3.2	93.5
	6.00	1	.0	3.2	96.8
	7.00	1	.0	3.2	100.0
	.	2696	98.9	MISSING	
	TOTAL	2727	100.0	100.0	

COUNT	VALUE	ONE SYMBOL EQUALS APPROXIMATELY .50 OCCURRENCES
21	1.00	**********
7	2.00	**********
1	3.00	**
0	4.00	
0	5.00	
1	6.00	**
1	7.00	**

I.....I.....I.....I.....I.....I
0 5 10 15 20 25
HISTOGRAM FREQUENCY

MEAN	1.645	MEDIAN	1.000	STD DEV	1.404
VARIANCE	1.970	SKEWNESS	3.007	S E SKEW	.421
MINIMUM	1.000	MAXIMUM	7.000		

VALID CASES 31 MISSING CASES 2696

XAF

VALUE LABEL	VALUE	FREQUENCY	PERCENT	VALID PERCENT	CUM PERCENT
	1.00	8	.3	25.8	25.8
	2.00	2	.1	6.5	32.3
	4.00	2	.1	6.5	38.7
	6.00	1	.0	3.2	41.9
	7.00	1	.0	3.2	45.2
	9.00	1	.0	3.2	48.4
	10.00	1	.0	3.2	51.6
	15.00	1	.0	3.2	54.8
	23.00	1	.0	3.2	58.1
	26.00	1	.0	3.2	61.3
	31.00	1	.0	3.2	64.5
	32.00	1	.0	3.2	67.7
	50.00	1	.0	3.2	71.0
	54.00	1	.0	3.2	74.2
	57.00	1	.0	3.2	77.4
	83.00	1	.0	3.2	80.6
	94.00	1	.0	3.2	83.9
	101.00	1	.0	3.2	87.1
	217.00	1	.0	3.2	90.3
	221.00	2	.1	6.5	96.8
	256.00	1	.0	3.2	100.0
	.	2696	98.9	MISSING	
	TOTAL	2727	100.0	100.0	

XAF

COUNT	MIDPOINT	ONE SYMBOL EQUALS APPROXIMATELY .40 OCCURRENCES
12	-1	**********
5	12	**********
3	25	********
1	38	***
3	51	********
0	64	
1	77	***
1	90	***
1	103	***
0	116	
0	129	
0	142	
0	155	
0	168	
0	181	
0	194	
0	207	
3	220	********
0	233	
0	246	
1	259	***

I....+....I....+....I....+....I....+....I....+....I....+....I
0 4 8 12 16 20
HISTOGRAM FREQUENCY

MEAN	49.452	MEDIAN	10.000	STD DEV	75.899
VARIANCE	5760.589	SKEWNESS	1.809	S E SKEW	.421
MINIMUM	1.000	MAXIMUM	256.000		

VALID CASES 31 MISSING CASES 2696

PRECEDING TASK REQUIRED 1.25 SECONDS CPU TIME; 18.94 SECONDS ELAPSED.

THERE ARE 67560 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS 67560 BYTES.

***** WORKSPACE ALLOWS FOR 3214 CASES FOR NPAR TESTS *****

```
PRECEDING TASK REQUIRED       0.41 SECONDS CPU TIME;      14.30 SECONDS ELAPSED.

 101  0          FINISH

   101 COMMAND LINES READ.
     0 ERRORS DETECTED.
     0 WARNINGS ISSUED.
     2 SECONDS CPU TIME.
    36 SECONDS ELAPSED TIME.
       END OF JOB.
```

Appendix C.4 Multiple Activity Sequence Analysis

```
/INFO  MVS  MSGLEVEL(1) CL(32) T(75)  PA(9999)   R(MUSIC)
// EXEC SPSSX
//IN DD DSN=#MCH.ARCTIC3,DISP=SHR
//FIN DD DSN=#MCH.AMA3,DISP=OLD
TITLE ACTIVITY SEQUENCE ANALYSIS: ARCTIC OFFICERS
COMMENT  REMEMBER TO CHANGE FIN FILE SPECIFICATION ON EACH RUN
GET FILE=IN
COMMENT  SPSS FILE TO ESTABLISH THE LENGTH AND NUMBER OF ACTIVITY
  SEQUENCES FOR EACH PERSON.  THIS IS DONE BY FIRST COMBINING THE
  ACTIVITY RECORDS UNDER A SEPARATE VARIABLE VALUE FOR EACH PERSON
  ABOUT WHOM RECORDS HAVE BEEN KEPT.  THIS PART OF THE PROGRAM IS
  COMMON WITH THE BEGINNING OF THE MULTIPLE RESPONSE PROGRAM.
  THEN THE INDIVIDUAL CASES ARE TESTED LOGICALLY FOR THE PRESENCE OF
  ONE OF FOUR DIFFERENT ACTIVITIES.  IF ONE OF THE ACTIVITIES IS
  PRESENT, THE ACTIVITY INDEX IS SET TO THE FIRST OF THE ACTIVITIES
  WHICH IS ENCOUNTERED.  THIS MEANS THAT THE ORDER IN WHICH THE
  ACTIVITIES ARE ENTERED (NA1, NA2, NA3, NA4) IS VITAL IN ASSIGNING
  PRIORITY TO WHICH ACTIVITY WILL DOMINATE IN THE SEQUENCE OF
  SUCCESSIVE ACTIVITIES.  IF NONE OF THE ACTIVITIES IS PRESENT,
  THE ACTIVITY INDEX IS SET TO 0.  THE TRANSITION PROBABILITIES
  BETWEEN SUCCESSIVE ACTIVITES ARE TABLUATED IN ONE TABLE, ALONG
  WITH THE CHI-SQUARE PROBABILITIES THAT THE DISTRIBUTIONS ARE
  INDEPENDENT.  IN A SECOND TABLE, THE VALUES FOR THE OVERLAP INDEX
  WHICH COUNTS THE NUMBER OF SUPPRESSED SIMULTANEOUS ACTIVITIES IS
  RECORDED FOR EACH OF THE ACTIVITIES.  THE ACTIVITY INDEX HAS THE
  VALUE OF THE ACTIVITY WHICH WAS DOMINANT (FIRST ENCOUNTERED) ON
  THAT TRIAL.  THE NEXT PART OF THE PROGRAM STARTS AN INDEX WHICH
  INCREMENTS AS LONG AS THE SAME ACTIVITY IS ENCOUNTERED ON
  SUCCESSIVE TRIALS.  WHEN A NEW ACTIVITY IS ENCOUNTERED, A PRINT
  INDEX TRIGGERS THE SELECTION OF THAT TRIAL, WHICH LEADS TO THE
  WRITING OF A RECORD CONTAINING THE INDEX NUMBER AND DURATION (IN
  UNITS OF SUCCESSIVE TRIALS) OF THE IMMEDIATELY PRECEDING ACTIVITY.
  THE RECORD IS WRITTEN AND A FREQUENCY HISTOGRAM FOR THE ACTIVITY
  AND THE ACTIVITY LENGTH IS CALCULATED.
RECODE ID1 TO ID6 (20,30=1) (21,31=2) (22,32=3) (23,33=4)
                  (24,34=5) (25,35=6) (26,36=7) (27,37=8)
                  (28,38=8) (29,39=9)
RECODE NTR1, NTR5, NTR9, NTR13, NTR17, NTR21 (1,2,3=1) (4,5=2) /*ARCTIC
   (6=3) (7,8=4) (9,10,11,12=5) (ELSE=SYSMIS) /* ARCTIC POSITION RECODE
VALUE LABELS NTR1, NTR5, NTR9, NTR13, NTR17, NTR21  1 'PORT FWD'
   2 'MAIN CONSOLE'  3  'STBD RDR'  4 'STBD FWD' /* ARCTIC VALUES
   5 'CHART AND TABLE' /*  ARCTIC POSITION VALUE LABELS
VARIABLE LABELS  NTR1 'POSN1' NTR5 'POSN2'  NTR9 'POSN3'
   NTR13 'POSN4'  NTR17 'POSN5'  NTR21 'POSN6'/* VL ALL SETS
RECODE NTR2,NTR3,NTR4,NTR6,NTR7,NTR8,NTR10,NTR11,NTR12,NTR14,NTR15,
   NTR16,NTR18,NTR19,NTR20,NTR22,NTR23,NTR24 (20,21,22,23= 1)
   (24,25=2) (33,34,35,37,=3) (5,70=4) (50=5) (ELSE=SYSMIS) /* A ACTS
VALUE LABELS NTR2,NTR3,NTR4,NTR6,NTR7,NTR8,NTR10,NTR11,
    NTR12,NTR14,NTR15,NTR16,NTR18,NTR19,NTR20,NTR22,NTR23,NTR24
    1 'VISION'  2 'RADAR'  3 'COMMUNICATION'  4 'CONTROL' /* ACT V LABEL
    5 'NAVIGATION'/*  ARCTIC ACT VALUE LABELS
VECTOR POSN, ACTI, ACTII, ACTIII (9)
COMPUTE POSN(ID1) = NTR1
IF (MISSING(ID2)=0)  POSN(ID2) = NTR5
IF (MISSING(ID3)=0)  POSN(ID3) = NTR9
IF (MISSING(ID4)=0)  POSN(ID4) = NTR13
IF (MISSING(ID5)=0)  POSN(ID5) = NTR17
IF (MISSING(ID6)=0)  POSN(ID6) = NTR21
```

```
COMPUTE ACTI(ID1) = NTR2
IF (MISSING(ID2)=0)  ACTI(ID2) = NTR6
IF (MISSING(ID3)=0)  ACTI(ID3) = NTR10
IF (MISSING(ID4)=0)  ACTI(ID4) = NTR14
IF (MISSING(ID5)=0)  ACTI(ID5) = NTR18
IF (MISSING(ID6)=0)  ACTI(ID6) = NTR22
COMPUTE ACTII(ID1) = NTR3
IF (MISSING(ID2)=0)  ACTII(ID2) = NTR7
IF (MISSING(ID3)=0)  ACTII(ID3) = NTR11
IF (MISSING(ID4)=0)  ACTII(ID4) = NTR15
IF (MISSING(ID5)=0)  ACTII(ID5) = NTR19
IF (MISSING(ID6)=0)  ACTII(ID6) = NTR23
COMPUTE ACTIII(ID1) = NTR4
IF (MISSING(ID2)=0)  ACTIII(ID2) = NTR8
IF (MISSING(ID3)=0)  ACTIII(ID3) = NTR12
IF (MISSING(ID4)=0)  ACTIII(ID4) = NTR16
IF (MISSING(ID5)=0)  ACTIII(ID5) = NTR20
IF (MISSING(ID6)=0)  ACTIII(ID6) = NTR24
NUMERIC  A1X, A2X, A3X, A4X, ACT, NPER, OVLP
NUMERIC  NX, PRINT, LACT, AIX, INXACT, DATA
                  /*
COMPUTE  DATA =5  /* THIS IS AN ARBRITRARY INDEX WHICH CAN BE SET
                  /* TO ANY VALUE.  IT IS PRINTED AS THE FIRST VARIABLE
                  /* ON THE PRINT OUTPUT AND THE DATA FILE. IT CAN BE
                  /* USED TO IDENTIFY THE DATA IN A CODEBOOK.
                  /*
COMPUTE  NA1=  5  /* THESE NA1 TO NA4 VALUES RANGE OVER ALL OF THE
COMPUTE  NA2=  3  /* NUMBERED ACTIVITIES.THE ACTIVITY SEQUENCE
COMPUTE  NA3=  2  /* CAN BE SHORTENED BY DUPLICATING AN EARLIER ACTIVITY
COMPUTE  NA4=  1  /* FOR THE EXTRA SEQUENCE VALUES. FOR EXAMPLE, BOTH
                  /* NA3 AND NA4 CAN BE 26, GIVING A THREE-ACTIVITY
                  /* SEQUENCE.  ALL ACTIVITIES NOT INDEXED AS NA1,NA2,
                  /* NA3 OR NA4 ARE INDEXED AS ZERO.
                  /*
                  /*
                  /* USE THIS SPACE TO NAME THE NUMBERED ACTIVITY
                  /* VARIABLES.
                  /*
                  /* 5 = NAVIGATION
                  /* 3 = COMMUNICATION
                  /* 2 = RADAR USE (ALL VARIETIES)
                  /* 1 = VISION
                  /* 0 = HAS BEEN CODED TO INCLUDE NAVIGATION AND NONOP
COMPUTE NPER = 4  /* THIS VALUE CHANGES FOR A CHANGE IN THE PERSON
                  /* ITS RANGE IS 1 - 9.  OTHER VALUES RECORDED IN
                  /* THE THULELAND AND KIGORIAK FILES ARE RECODED TO
                  /* THE RANGE 1-9 BY A RECODE STATEMENT. REFER TO THE
                  /* RECODE STATEMENT TO IDENTIFY THE PERSON WHOSE DATA
                  /* IS ANALYZED.
                  /*
COMPUTE  A1X=0
COMPUTE  A2X=0
COMPUTE  A3X=0
COMPUTE  A4X=0
COMPUTE  ACT=0
COMPUTE  OVLP=0
DO IF ((ACTI(NPER)=NA1) OR (ACTII(NPER)=NA1) OR (ACTIII(NPER)=NA1))
+    COMPUTE A1X=NA1
```

```
+    COMPUTE OVLP = OVLP + 1
END IF
DO IF ((ACTI(NPER)=NA2) OR (ACTII(NPER)=NA2) OR (ACTIII(NPER)=NA2))
+    COMPUTE A2X=NA2
+    COMPUTE OVLP = OVLP + 1
END IF
DO IF ((ACTI(NPER)=NA3) OR (ACTII(NPER)=NA3) OR (ACTIII(NPER)=NA3))
+    COMPUTE A3X=NA3
+    COMPUTE OVLP = OVLP + 1
END IF
DO IF ((ACTI(NPER)=NA4) OR (ACTII(NPER)=NA4) OR (ACTIII(NPER)=NA4))
+    COMPUTE A4X=NA4
+    COMPUTE OVLP = OVLP + 1
END IF
DO IF ((SYSMIS(A1X)=0) AND (MISSING(A1X)=0) AND (A1X NE 0))
+    COMPUTE    A2X = 0
+    COMPUTE    A3X = 0
+    COMPUTE    A4X = 0
END IF
DO IF ((SYSMIS(A2X)=0) AND (MISSING(A2X)=0) AND (A2X NE 0))
+    COMPUTE  A3X = 0
+    COMPUTE  A4X = 0
END IF
DO IF ((SYSMIS(A3X)=0) AND (MISSING(A3X)=0) AND (A3X NE 0))
+    COMPUTE A4X = 0
END IF
COMPUTE  ACT = MAX(A1X, A2X, A3X, A4X)
COMPUTE INXACT = LAG(ACT,1)
DO IF ((SYSMIS(INXACT)) OR (MISSING(INXACT)))
+    COMPUTE PRINT = 2
+    COMPUTE AIX = ACT
+    COMPUTE NX = 1
+    COMPUTE LACT = 1
ELSE IF (ACT EQ INXACT)
+    COMPUTE NX = LAG(NX,1) + 1
+    COMPUTE PRINT = 0
+    COMPUTE AIX = ACT
+    COMPUTE LACT = NX
ELSE
+    COMPUTE LACT = LAG(NX,1)
+    COMPUTE AIX = LAG(ACT,1)
+    COMPUTE NX = 1
+    COMPUTE PRINT = 1
END IF
  /*
  /*  THIS CROSSTABULATION GIVES THE TRANSITION MATRIX FOR ALL OF THE
  /*  RECORDED ACTIVITIES.  THE SECOND CROSSTABULATION GIVES THE AMOUNT
  /*  OF OVERLAP RECORDED FOR TRIALS ON WHICH PARTICULAR ACTIVITIES WERE
  /*  DOMINANT
  /*
CROSSTABS TABLES = INXACT BY ACT/ OVLP BY ACT
OPTIONS  14
STATISTICS 1
SELECT IF (PRINT EQ 1)
PRINT OUTFILE=FIN TABLE / DATA SHIP IDNUM NPER SEQNO AIX LACT
EXECUTE
  /*
  /*  THIS CROSSTABS GIVES THE TRANSITION PROB'S FOR ACT SEQUENCES
```

```
  /*  IN OTHER WORDS, FOR THE TRANSITION BETWEEN ANY ONE ACT CONTINUED
  /*  FOR HOWEVER LONG, AND THE NEXT ACT.
  /*
CROSSTABS TABLES = INXACT BY ACT
OPTIONS 14
STATISTICS 1
  /*
  /*  THIS FREQUENCIES COUNT OF SEQUENCE LENGTHS IS FOR THE FIRST OR
  /*  DOMINANT ACTIVITY SELECTED.
  /*
SELECT IF (ACT EQ NA1)
FREQUENCIES  VARIABLES = LACT/
             STATISTICS  DEFAULT VARIANCE MEDIAN SKEWNESS SESKEW
  /*
  /*
  /*
  /*

FINISH
```

CROSSTABULATION OF INXACT BY ACT

PAGE 1 OF 1

INXACT	COUNT / EXP VAL	.00	1.00	2.00	3.00	4.00	ROW TOTAL
.00		3772	133	60	21	10	3996
		2858.1	672.3	194.5	212.4	58.6	71.5%
1.00		122	608	61	115	34	940
		672.3	158.2	45.8	50.0	13.8	16.8%
2.00		64	53	127	25	3	272
		194.5	45.8	13.2	14.5	4.0	4.9%
3.00		26	103	23	128	17	297
		212.4	50.0	14.5	15.8	4.4	5.3%
4.00		12	43	1	8	18	82
		58.6	13.8	4.0	4.4	1.2	1.5%
COLUMN TOTAL		3996	940	272	297	82	5587
		71.5%	16.8%	4.9%	5.3%	1.5%	100.0%

CHI-SQUARE	D.F.	SIGNIFICANCE	MIN E.F.	CELLS WITH E.F.< 5
5351.71156	16	0.0	1.204	5 OF 25 (20.0%)

NUMBER OF MISSING OBSERVATIONS = 1

02 SEP 85 ACTIVITY SEQUENCE ANALYSIS: LIST-ONLY VERSION PAGE 6
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CROSSTABULATION OF OVLP BY ACT

PAGE 1 OF 1

OVLP	COUNT / EXP VAL	.00	1.00	2.00	3.00	4.00	ROW TOTAL
.00		3997	0	0	0	0	3997
		2859.0	672.4	194.6	212.4	58.7	71.5%
1.00		0	940	272	90	48	1350
		965.6	227.1	65.7	71.8	19.8	24.2%
2.00		0	0	0	207	34	241
		172.4	40.5	11.7	12.8	3.5	4.3%
COLUMN TOTAL		3997	940	272	297	82	5588
		71.5%	16.8%	4.9%	5.3%	1.5%	100.0%

CHI-SQUARE	D.F.	SIGNIFICANCE	MIN E.F.	CELLS WITH E.F.< 5

```
----------    ----      ------------        --------      ------------------

 8918.05885        8          0.0                3.537      1 OF    15 (  6.7%)
NUMBER OF MISSING OBSERVATIONS =        0
02 SEP 85    ACTIVITY SEQUENCE ANALYSIS: LIST-ONLY VERSION                                    PAGE    7
22:09:38     MCGILL UNIVERSITY              AMDAHL 5801       MVS 3.8

PRECEDING TASK REQUIRED        4.14 SECONDS CPU TIME;       37.70 SECONDS ELAPSED.

 167  0           SELECT IF (PRINT EQ 1)
 168  0           LIST VARIABLES= DATA SHIP IDNUM NPER SEQNO AIX LACT
THERE ARE     70480 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS     70480 BYTES.
       663 BYTES OF MEMORY REQUIRED FOR LIST PROCEDURE.
       432 BYTES HAVE ALREADY BEEN ACQUIRED.
       231 BYTES REMAIN TO BE ACQUIRED.

02 SEP 85    ACTIVITY SEQUENCE ANALYSIS: LIST-ONLY VERSION                                    PAGE    8
22:09:40     MCGILL UNIVERSITY              AMDAHL 5801       MVS 3.8
```

DATA	SHIP	IDNUM	NPER	SEQNO	AIX	LACT
1.00	A	3070322	1.00	13	.00	12.00
1.00	A	3070322	1.00	15	2.00	2.00
1.00	A	3070322	1.00	58	.00	43.00
1.00	A	3070322	1.00	60	2.00	2.00
1.00	A	3070322	1.00	80	.00	20.00
1.00	A	3070322	1.00	81	2.00	1.00
1.00	A	3070322	1.00	134	.00	53.00
1.00	A	3070322	1.00	135	2.00	1.00
1.00	A	3070322	1.00	184	.00	49.00
1.00	A	3070322	1.00	186	2.00	2.00
1.00	A	3070333	1.00	6	.00	152.00
1.00	A	3070333	1.00	7	2.00	1.00
1.00	A	3070333	1.00	50	.00	43.00
1.00	A	3070333	1.00	54	2.00	4.00
1.00	A	3070333	1.00	294	.00	240.00
1.00	A	3070333	1.00	296	2.00	2.00
1.00	A	3070403	1.00	57	.00	73.00
1.00	A	3070403	1.00	58	2.00	1.00
1.00	A	3070403	1.00	76	.00	18.00
1.00	A	3070403	1.00	77	2.00	1.00
1.00	A	3070403	1.00	80	.00	3.00
1.00	A	3070403	1.00	85	2.00	5.00
1.00	A	3070403	1.00	90	.00	5.00
1.00	A	3070403	1.00	93	2.00	3.00
1.00	A	3070403	1.00	97	.00	4.00
1.00	A	3070403	1.00	100	2.00	3.00
1.00	A	3070403	1.00	102	.00	2.00
1.00	A	3070403	1.00	105	2.00	3.00
1.00	A	3070403	1.00	148	.00	43.00
1.00	A	3070403	1.00	149	2.00	1.00
1.00	B	3102406	1.00	67	.00	1930.00
1.00	B	3102406	1.00	80	3.00	13.00
1.00	A	3102412	1.00	36	.00	37.00
1.00	A	3102412	1.00	41	1.00	5.00
1.00	A	3102412	1.00	42	3.00	1.00

```
     1.00 A    3102412     1.00   47      1.00     5.00
     1.00 A    3102412     1.00   48       .00     1.00
     1.00 A    3102412     1.00   50      1.00     2.00
     1.00 A    3102412     1.00   51       .00     1.00
     1.00 A    3102412     1.00   56      1.00     5.00
     1.00 A    3102412     1.00   57       .00     1.00
     1.00 A    3102412     1.00   59      1.00     2.00
     1.00 A    3102412     1.00   60       .00     1.00
     1.00 A    3102412     1.00   72      1.00    12.00
     1.00 A    3102412     1.00   73       .00     1.00
     1.00 A    3102412     1.00   75      1.00     2.00
     1.00 A    3102412     1.00   77       .00     2.00
     1.00 A    3102412     1.00   78      2.00     1.00
     1.00 A    3102801     1.00  566      3.00     1.00

-------------872 ADDITIONAL CASES----------------

     1.00 A    3102801     1.00  569      1.00     3.00
     1.00 A    3102801     1.00  570      3.00     1.00
     1.00 A    3102801     1.00  577      1.00     7.00
     1.00 A    3102801     1.00  578      3.00     1.00
     1.00 A    3102801     1.00  579       .00     1.00
     1.00 A    3102801     1.00  581      1.00     2.00
     1.00 A    3102801     1.00  582       .00     1.00
     1.00 A    3102801     1.00  583      3.00     1.00
     1.00 A    3102801     1.00  594      1.00    11.00
     1.00 A    3102801     1.00  605      3.00    11.00
     1.00 A    3102801     1.00  606       .00     1.00
     1.00 A    3102801     1.00  609      3.00     3.00
     1.00 A    3102801     1.00  610       .00     1.00
     1.00 A    3102801     1.00  611      4.00     1.00
     1.00 A    3102801     1.00  614      1.00     3.00
-NUMBER OF CASES READ =     934    NUMBER OF CASES LISTED =     934
 02 SEP 85    ACTIVITY SEQUENCE ANALYSIS: LIST-ONLY VERSION                    PAGE  27
 22:10:11     MCGILL UNIVERSITY              AMDAHL 5801      MVS 3.8

 PRECEDING TASK REQUIRED       1.03 SECONDS CPU TIME;      31.76 SECONDS ELAPSED.

  169  0          EXECUTE
  170  0            /*
  171  0            /*  THIS CROSSTABS GIVES THE TRANSITION PROB'S FOR ACT SEQUENCES
  172  0            /*  IN OTHER WORDS, FOR THE TRANSITION BETWEEN ANY ONE ACT CONTINUED
  173  0            /*  FOR HOWEVER LONG, AND THE NEXT ACT.
  174  0            /*
 02 SEP 85    ACTIVITY SEQUENCE ANALYSIS: LIST-ONLY VERSION                    PAGE  28
 22:10:15     MCGILL UNIVERSITY              AMDAHL 5801      MVS 3.8

 PRECEDING TASK REQUIRED       0.11 SECONDS CPU TIME;       4.54 SECONDS ELAPSED.

  175  0          CROSSTABS TABLES = INXACT BY ACT
  176  0          OPTIONS 14
  177  0          STATISTICS 1
  178  0            /*
  179  0            /*  THIS FREQUENCIES COUNT OF SEQUENCE LENGTHS IS FOR THE FIRST OR
  180  0            /*  DOMINANT ACTIVITY SELECTED.
  181  0            /*

 THERE ARE    71064 BYTES OF MEMORY AVAILABLE.
```

```
THE LARGEST CONTIGUOUS AREA HAS    71064 BYTES.
 ***** GIVEN WORKSPACE ALLOWS FOR  2368 CELLS WITH     2 DIMENSIONS FOR CROSSTAB PROBLEM *****

02 SEP 85   ACTIVITY SEQUENCE ANALYSIS: LIST-ONLY VERSION                                    PAGE  29
22:10:20    MCGILL UNIVERSITY              AMDAHL 5801      MVS 3.8

- - - - - - - - - - - - - - - - - - - - -  C R O S S T A B U L A T I O N   O F  - - - - - - - - - - - - - - - - - - - -
    INXACT                                                          BY  ACT
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -  PAGE  1 OF  1

                ACT
          COUNT  I
         EXP VAL I                                                          ROW
                 I                                                          TOTAL
                 I     .00I    1.00I    2.00I    3.00I    4.00I
INXACT   --------+--------+--------+--------+--------+--------+
            .00  I      0  I    133  I     60  I     21  I     10  I    224
                 I   53.7  I   79.6  I   34.8  I   40.5  I   15.3  I   24.0%
                 +--------+--------+--------+--------+--------+
           1.00  I    122  I      0  I     61  I    115  I     34  I    332
                 I   79.6  I  118.0  I   51.5  I   60.1  I   22.7  I   35.5%
                 +--------+--------+--------+--------+--------+
           2.00  I     64  I     53  I      0  I     25  I      3  I    145
                 I   34.8  I   51.5  I   22.5  I   26.2  I    9.9  I   15.5%
                 +--------+--------+--------+--------+--------+
           3.00  I     26  I    103  I     23  I      0  I     17  I    169
                 I   40.5  I   60.1  I   26.2  I   30.6  I   11.6  I   18.1%
                 +--------+--------+--------+--------+--------+
           4.00  I     12  I     43  I      1  I      8  I      0  I     64
                 I   15.3  I   22.7  I    9.9  I   11.6  I    4.4  I    6.9%
                 +--------+--------+--------+--------+--------+
         COLUMN       224       332       145       169        64       934
          TOTAL     24.0%     35.5%     15.5%     18.1%      6.9%    100.0%

 CHI-SQUARE     D.F.        SIGNIFICANCE         MIN E.F.       CELLS WITH E.F.< 5
 ----------     ----        ------------         --------       ------------------

  470.86287       16          0.0                  4.385        1 OF    25 (  4.0%)
NUMBER OF MISSING OBSERVATIONS =        0
02 SEP 85   ACTIVITY SEQUENCE ANALYSIS: LIST-ONLY VERSION                                    PAGE  30
22:10:20    MCGILL UNIVERSITY              AMDAHL 5801      MVS 3.8

PRECEDING TASK REQUIRED        0.17 SECONDS CPU TIME;        4.82 SECONDS ELAPSED.

  182  0          SELECT IF (ACT EQ NA1)
  183  0          FREQUENCIES  VARIABLES = LACT/
  184  0                       STATISTICS  DEFAULT VARIANCE MEDIAN SKEWNESS SESKEW
  185  0            /*
  186  0            /*  THIS NPAR K-S TEST IS FOR THE DISTRIBUTION OF SERIES LENGTHS
  187  0            /*  FOR THE FIRST OR DOMINANT ACTIVITY SELECTED.
  188  0            /*

THERE ARE     70896 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS     70896 BYTES.
***** MEMORY ALLOWS A TOTAL OF    3222 VALUES, ACCUMULATED ACROSS ALL VARIABLES.
      THERE ALSO MAY BE UP TO     806 VALUE LABELS FOR EACH VARIABLE.

102 SEP 85   ACTIVITY SEQUENCE ANALYSIS: LIST-ONLY VERSION                                   PAGE  31
```

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LACT

VALUE LABEL	VALUE	FREQUENCY	PERCENT	VALID PERCENT	CUM PERCENT
	1.00	40	62.5	62.5	62.5
	2.00	11	17.2	17.2	79.7
	3.00	4	6.3	6.3	85.9
	4.00	4	6.3	6.3	92.2
	5.00	2	3.1	3.1	95.3
	9.00	2	3.1	3.1	98.4
	11.00	1	1.6	1.6	100.0
	TOTAL	64	100.0	100.0	

MEAN	2.016	MEDIAN	1.000	STD DEV	2.020
VARIANCE	4.079	SKEWNESS	2.890	S E SKEW	.299
MINIMUM	1.000	MAXIMUM	11.000		

VALID CASES 64 MISSING CASES 0

PRECEDING TASK REQUIRED 0.14 SECONDS CPU TIME; 5.11 SECONDS ELAPSED.

```
 189  0          NPAR TESTS K-S (POISSON)  = LACT/
THERE ARE    67032 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS    67032 BYTES.
 ***** WORKSPACE ALLOWS FOR    3942 CASES FOR NPAR TESTS *****
```


PRECEDING TASK REQUIRED 0.03 SECONDS CPU TIME; 0.89 SECONDS ELAPSED.

```
 190  0          FINISH
   190 COMMAND LINES READ.
       END OF JOB.
```

Appendix D Test of Order of Markov Chain: Program Listing and Transition Matrix Output

The transition matrices which follow the program listing are annotated with row and column indices to aid in understanding them. The meaning of each index is explained in Table D.1. The table entries define the index terms which appear at the side of the table.

Table D.1. Definition of Index Terms for the Transition Matrices

Index Term	Definition
PW	Port wing
SW	Starboard wing
SR	Starboard Radar
Ch	Chart table
FC	Forward Console
V	Visual Observation
R	Radar Observation
C	Communications activity
N	Navigation activity
M	Manoeuvring or console activity

```
 C PROPRINC
C MAIN PROGRAM: ASKS FOR THE VARIOUS PARAMETERS OF THE FILE
C WE WANT TO ANALYSE
C
C
C DESCRIPTION OF MAIN PARAMETERS
C
C
C FILENAME-CODED NAME OF THE FILE
C FILENO-CODED NUMBER OF THE FILE
C SN-CODED NAME OF THE SHIP
C OF-NUMBER REPRESENTING OFFICER
C M-NUMBER OF CATEGORIES OF ACTIVITIES(POSITIONS)
C S(I)-VECTOR OF CODED NUMBERS FOR ACTIVITIES(POSITIONS)
C NT-TOTAL NUMBER OF OBSERVATIONS IN THE ORIGINAL FILE
C
C
C SUBROUTINES CALLED
C ESTPROB- SEE LISTING FOR DESCRIPTION
C
C
C
      CHARACTER*2 SN
      CHARACTER*10 TITLE
      CHARACTER*12 SHIP
      CHARACTER*10 OFFICER
      CHARACTER*11 FILENAME
      DIMENSION P1(15),P2(15,15),P3(15,15,15)
      DIMENSION PEST1(15),PEST2(15,15),PEST3(15,15,15)
      DIMENSION S(15)
      WRITE (108,8)
 8    FORMAT (' NAME OF FILE')
      READ (105,9) FILENAME
 9    FORMAT (A)
      OPEN (201,NAME=FILENAME,USAGE='INPUT')
      DO 7 I=1,2
     READ (201,10) FILENO,SN,J,OF,K,S(I)
 10  FORMAT (F9.2,A2,I8,F9.2,I4,F9.2)
 7   WRITE (108,10) FILENO,SN,J,OF,K,S(I)
      I1=S(1)
      J1=S(2)
      WRITE (108,11)
 11   FORMAT (' NO OF STATES AND NO OF CASES')
      READ (105,12) M,NT
 12   FORMAT (I4)
      WRITE (108,13)
 13   FORMAT (' ENUMERATE STATES-F9.2')
      READ (105,14)(S(I),I=1,M)
 14   FORMAT (F9.2)
      WRITE (108,20)
 20   FORMAT (' ACTIVITY OR POSITION?'/' SHIP?'/' OFFICER?')
      READ (105,99) TITLE,SHIP,OFFICER
 99   FORMAT (A10/A12/A10/)
      WRITE (108,98) TITLE,SHIP,OFFICER
 98   FORMAT (A10,' SEQUENCE ANALYSIS'/' SHIP:',A12,/' OFFICER:',A
      DO 15 K=1,M
      IF (I1.NE.S(K)) GO TO 16
      I1=K
 16   IF (J1.NE.S(K)) GO TO 15
      J1=K
 15   CONTINUE
      CALL ESTPROB(M,I1,J1,S,201,NT,P1,P2,P3,PEST1,PEST2,PEST3)
      CLOSE (201)
      STOP
      END
```

```
C
C FREQUENCY COUNTS                                SUBEST
C
      DO 5 L=3,NT
      READ (LOG,10) STATE
 10   FORMAT (32X,F9.2)
      IND=0
      DO 15 K=1,M
      IF (STATE.NE.S(K)) GO TO 15
      P3(I,J,K)=P3(I,J,K) +1
      P2(J,K)=P2(J,K)+1
      P1(K)=P1(K)+1
      I=J
      J=K
      IND=1
      GO TO 25
 15   CONTINUE
 25   IF (IND.EQ.0) NBUNID=NBUNID+1
 5    CONTINUE
      NTC=NT-NBUNID
      WRITE (108,26) NTC
 26   FORMAT (///' NUMBER OF OBSERVATIONS CONSIDERED: ',I3//)
C
C PROBABILITY ESTIMATION
C
      DO 40 I=1,M
      PEST1(I)=P1(I)/NTC
      DO 40 J=1,M
      IF (P1(J).NE.0) GO TO 41
      PEST1(I)=.001
      DO 42 L=1,M
  42  PEST2(I,L)=1./M
      GO TO 43
 41   PEST2(I,J)=P2(I,J)/P1(I)
 43   IF (P2(I,J).NE.0) GO TO 46
      PEST2(I,J)=.001
      DO 44 L=1,M
  44  PEST3(I,J,L)=1./M
      GO TO 40
 46   DO 45 K=1,M
  45  PEST3(I,J,K)=P3(I,J,K)/P2(I,J)
      CONTINUE
```

```
 C SUBEST
C
C SUBROUTINE ESTPROB: DETERMINES THE FREQUENCIES OF ZERO,FIRST AND
C SECOND ORDER TRANSITIONS BETWEEN STATES(ACTIVITIES OR POSITIONS)
C USES THESE FREQUENCIES TO ESTIMATE TRANSITION PROBABILITIES AND
C COMPUTES CHI-SQUARE STATISTICS TO TEST FOR THE ORDER OF THE CHAIN
C
C
C DESCRIPTION OF MAIN PARAMETERS
C
C M-NUMBER OF STATES CONSIDERED
C S(I)-CODED NUMBER OF STATE I
C NT-TOTAL NUMBER OF OBSERVATIONS IN THE ORIGINAL FILE
C NBUNID- TOTAL NUMBER OF OBSERVATIONS NOT CONSIDERED
C NTC- TOTAL NUMBER OF OBSERVATIONS CONSIDERED
C P1(I)-FREQUENCY OF STATE I
C P2(I,J)-FREQUENCY OF TRANSITIONS FROM I TO J
C P3(I,J,K)-FREQUENCY OF TRANSITIONS FROM I TO J TO K
C PEST1(I)-ESTIMATED PROBABILITY OF BEING IN STATE I
C PEST2(I,J)-ESTIMATED TRANSITION PROBABILITY FROM I TO J
C PEST3(I,J,K)-ESTIMATED TRANSITION PROBABILITY FROM I TO J TO K
C SS1-CHI-SQUARE STATISTICS FOR FIRST TEST
C SS2-CHI-SQUARE STATISTICS FOR SECOND TEST
C
C
C
      SUBROUTINE ESTPROB(M,I1,J1,S,LOG,NT,P1,P2,P3,PEST1,PEST2,PEST3)
      DIMENSION P1(M),P2(M,M),P3(M,M,M)
      DIMENSION PEST1(M),PEST2(M,M),PEST3(M,M,M)
      DIMENSION S(M)
C
C INITIALIZATION
C
      SS1=0.
      SS2=0.
      NBUNID=0
      DO 1 I=1,M
      P1(I)=0
      DO 1 J=1,M
      P2(I,J)=0
      DO 1 K=1,M
1     P3(I,J,K)=0
      I=I1
      P1(I)=1
      J=J1
      P2(I,J)=1
```

```
C CHI-SQUARE STATISTICS COMPUTATION          SUBEST
C
      DO 50 I=1,M
      DO 51 J=1,M
      SS1=SS1+P1(I)*(PEST2(I,J)-PEST1(J))**2/PEST1(J)
      DO 52 K=1,M
      SS2=SS2+P2(I,J)*(PEST3(I,J,K)-PEST2(J,K))**2/PEST2(J,K)
   52 CONTINUE
   51 CONTINUE
   50 CONTINUE
      WRITE (108,100)
  100 FORMAT (///,' FIRST-ORDER TRANSITION FREQUENCY MATRIX',//)
      DO 101 I=1,M
  101 WRITE (108,102) (P2(I,J),J=1,M)
  102 FORMAT (4F7.2)
      WRITE (108,103)
  103 FORMAT (///,' ESTIMATED TRANSITION PROBABILITY MATRIX'//)
      DO 104 I=1,M
  104 WRITE (108,102) (PEST2(I,J),J=1,M)
      WRITE (108,105)
  105 FORMAT (///,' SECOND-ORDER TRANSITION FREQUENCY MATRICES',//)
      DO 106 I=1,M
      WRITE (108,109)
  109 FORMAT (/)
      DO 106 J=1,M
  106 WRITE (108,102) (P3(I,J,K),K=1,M)
      WRITE  (108,107)
  107 FORMAT (///,' ESTIMATED TRANSITION PROBABILITY MATRICES',//)
      DO 108 I=1,M
      WRITE (108,109)
      DO 108 J=1,M
  108 WRITE (108,102) (PEST3(I,J,K),K=1,M)
      WRITE (108,120)
  120 FORMAT (///,' TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY',//)
      MDF1=(M-1)**2
      MDF2=M*MDF1
      WRITE (108,121) MDF1,SS1
  121 FORMAT (' CHI-SQUARE STATISTIC(',I2,' D.F.): ',F7.2)
      WRITE (108,122)
  122 FORMAT (///,' TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY',//)
      WRITE (108,121) MDF2,SS2
      RETURN
      END
```

POSITION SEQUENCE ANALYSIS
SHIP: ARCTIC
OFFICER: CAPTAIN

NUMBER OF OBSERVATIONS CONSIDERED: 363

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	PW	FC	SW	CH
PW	4.00	27.00	16.00	5.00
FC	23.00	18.00	31.00	16.00
SW	19.00	31.00	30.00	56.00
CH	6.00	11.00	59.00	10.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	PW	FC	SW	CH
PW	.08	.53	.31	.10
FC	.26	.20	.35	.18
SW	.14	.23	.22	.41
CH	.07	.13	.68	.11

SECOND-ORDER TRANSITION FREQUENCY MATRICES

PW:	PW	FC	SW	CH
PW	.00	1.00	3.00	.00
FC	8.00	8.00	6.00	5.00
SW	8.00	2.00	4.00	2.00
CH	2.00	.00	2.00	.00

FC:				
PW	2.00	14.00	6.00	1.00
FC	3.00	7.00	4.00	4.00
SW	4.00	14.00	4.00	9.00
CH	3.00	4.00	6.00	3.00

SW:				
PW	2.00	9.00	6.00	2.00
FC	6.00	2.00	17.00	6.00
SW	4.00	7.00	7.00	12.00
CH	1.00	6.00	43.00	6.00

CH:				
PW	.00	3.00	1.00	2.00
FC	5.00	1.00	4.00	1.00
SW	3.00	8.00	15.00	33.00
CH	.00	1.00	8.00	1.00

ESTIMATED TRANSITION PROBABILITY MATRICES
ARCTIC CAPTAIN

PW:	PW	FC	SW	CH
PW	.00	.25	.75	.00
FC	.30	.30	.22	.19
SW	.50	.13	.25	.13
CH	.40	.00	.40	.00
FC:				
PW	.09	.61	.26	.04
FC	.17	.39	.22	.22
SW	.13	.45	.13	.29
CH	.19	.25	.38	.19
SW:				
PW	.11	.47	.32	.11
FC	.19	.06	.55	.19
SW	.13	.23	.23	.40
CH	.02	.11	.77	.11
CH:				
PW	.00	.50	.17	.33
FC	.45	.09	.36	.09
SW	.05	.14	.25	.56
CH	.00	.10	.80	.10

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 95.09 $p < .005$

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY
Chi square (36 d. f.) = 85.14, $p < .005$

POSITION SEQUENCE ANALYSIS
SHIP: ARCTIC
OFFICER: MATE1

NUMBER OF OBSERVATIONS CONSIDERED: 166

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	PW	FC	SW	CH
PW	9.00	17.00	9.00	5.00
FC	15.00	8.00	15.00	8.00
SW	9.00	13.00	12.00	14.00
CH	7.00	8.00	12.00	4.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	PW	FC	SW	CH
PW	.22	.42	.22	.13
FC	.32	.17	.32	.17
SW	.19	.28	.26	.30
CH	.23	.26	.39	.13

SECOND-ORDER TRANSITION FREQUENCY MATRICES

PW:	PW	FC	SW	CH
PW	1.00	6.00	2.00	.00
FC	6.00	6.00	4.00	.00
SW	2.00	2.00	3.00	2.00
CH	2.00	3.00	.00	.00

FC:				
PW	4.00	6.00	1.00	4.00
FC	2.00	1.00	3.00	2.00
SW	2.00	6.00	3.00	4.00
CH	1.00	1.00	5.00	1.00

SW:				
PW	1.00	3.00	4.00	1.00
FC	2.00	.00	7.00	4.00
SW	2.00	2.00	3.00	5.00
CH	3.00	3.00	5.00	3.00

CH:				
PW	3.00	2.00	2.00	.00
FC	5.00	1.00	.00	2.00
SW	3.00	3.00	3.00	3.00
CH	1.00	1.00	2.00	.00

ESTIMATED TRANSITION PROBABILITY MATRICES :

ARCTIC MATE 1

PW:	PW	FC	SW	CH
PW	.11	.67	.22	.00
FC	.35	.35	.24	.00
SW	.22	.22	.33	.22
CH	.40	.60	.00	.00

FC:				
PW	.27	.40	.07	.27
FC	.25	.13	.38	.25
SW	.13	.40	.20	.27
CH	.13	.13	.63	.13

SW:				
PW	.11	.33	.44	.11
FC	.15	.00	.54	.31
SW	.17	.17	.25	.42
CH	.21	.21	.36	.21

CH:				
PW	.43	.29	.29	.00
FC	.63	.13	.00	.25
SW	.25	.25	.25	.25
CH	.25	.25	.50	.00

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 13.33 n. s.

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(36 D.F.): 44.12 n. s.

POSITION SEQUENCE ANALYSIS
SHIP: ARCTIC
OFFICER: MATE2

NUMBER OF OBSERVATIONS CONSIDERED: 106

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	PW	FC	SW	CH
PW	2.00	9.00	3.00	3.00
RC	9.00	25.00	14.00	4.00
SW	6.00	11.00	4.00	4.00
CH	.00	7.00	4.00	.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	PW	FC	SW	CH
PW	.13	.56	.19	.19
FC	.17	.47	.26	.08
SW	.24	.44	.16	.16
CH	.00	.64	.36	.00

SECOND-ORDER TRANSITION FREQUENCY MATRICES

PW:

PW:	PW	FC	SW	CH
PW	1.00	1.00	.00	.00
FC	4.00	3.00	2.00	.00
SW	.00	2.00	.00	1.00
CH	.00	1.00	2.00	.00

FC:

PW	1.00	3.00	3.00	2.00
FC	3.00	11.00	7.00	3.00
SW	3.00	8.00	3.00	.00
CH	.00	2.00	2.00	.00

SW:

PW	.00	5.00	.00	1.00
FC	1.00	7.00	2.00	1.00
SW	2.00	1.00	.00	1.00
CH	.00	4.00	.00	.00

CH:

PW	.00	.00	.00	.00
FC	.00	4.00	3.00	.00
SW	1.00	.00	1.00	2.00
CH	.00	.00	.00	.00

ACTIVITY SEQUENCE ANALYSIS
SHIP: ARCTIC
OFFICER: MATE1

NUMBER OF OBSERVATIONS CONSIDERED: 273

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	V	R	C	N
V	75.00	28.00	7.00	31.00
R	26.00	9.00	6.00	16.00
C	11.00	3.00	1.00	2.00
N	31.00	16.00	3.00	7.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	V	R	C	N
V	.53	.20	.05	.22
R	.46	.16	.11	.29
C	.65	.18	.06	.12
N	.55	.29	.05	.13

SECOND-ORDER TRANSITION FREQUENCY MATRICES

V:

	V	R	C	N
V	46.00	10.00	4.00	14.00
R	13.00	3.00	5.00	7.00
C	6.00	1.00	.00	.00
N	16.00	8.00	1.00	6.00

R:

V	11.00	5.00	3.00	7.00
R	2.00	5.00	1.00	1.00
C	3.00	2.00	.00	1.00
N	8.00	7.00	1.00	.00

C:

V	4.00	3.00	.00	4.00
R	3.00	.00	.00	.00
C	1.00	.00	.00	.00
N	1.00	.00	1.00	.00

N:

V	14.00	11.00	.00	6.00
R	8.00	.00	.00	8.00
C	1.00	.00	1.00	1.00
N	5.00	1.00	.00	1.00

ESTIMATED TRANSITION PROBABILITY MATRICES

ARCTIC CAPTAIN

V:	V	R	C	N
V	.36	.25	.33	.06
R	.69	.06	.17	.08
C	.91	.06	.01	.02
N	.81	.19	.00	.00
R:				
V	.36	.42	.15	.07
R	.17	.50	.17	.17
C	.45	.52	.00	.03
N	.08	.67	.25	.00
C:				
V	.24	.13	.62	.01
R	.38	.29	.29	.04
C	.50	.00	.50	.00
N	.40	.20	.00	.40
N:				
V	.26	.26	.26	.21
R	.50	.17	.33	.00
C	.33	.33	.00	.33
N	1.00	.00	.00	.00

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 147.23 $p < .005$

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY

Chi square (36 d. f.) = 230.72 $p < .005$

ACTIVITY SEQUENCE ANALYSIS
SHIP: ARCTIC
OFFICER: CAPTAIN

NUMBER OF OBSERVATIONS CONSIDERED: 676

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	V	R	C	N
V	100.00	78.00	133.00	16.00
R	74.00	30.00	29.00	12.00
C	136.00	24.00	2.00	5.00
N	19.00	12.00	3.00	2.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	V	R	C	N
V	.30	.24	.41	.05
R	.51	.21	.20	.08
C	.81	.14	.01	.03
N	.54	.34	.09	.06

SECOND-ORDER TRANSITION FREQUENCY MATRICES

V:

	V	R	C	N
V	36.00	25.00	33.00	6.00
R	54.00	5.00	13.00	6.00
C	121.00	8.00	1.00	3.00
N	13.00	3.00	.00	.00

R:

V	27.00	31.00	11.00	5.00
R	5.00	15.00	5.00	5.00
C	13.00	15.00	.00	1.00
N	1.00	8.00	3.00	.00

C:

V	32.00	18.00	84.00	1.00
R	9.00	7.00	7.00	1.00
C	1.00	.00	1.00	.00
N	2.00	1.00	.00	2.00

N:

V	5.00	5.00	5.00	4.00
R	6.00	2.00	4.00	.00
C	1.00	1.00	.00	1.00
N	2.00	.00	.00	.00

ESTIMATED TRANSITION PROBABILITY MATRICES : ARCTIC MATE 2

PW:	PW	FC	SW	CH
PW	.50	.50	.00	.00
FC	.44	.33	.22	.00
SW	.00	.67	.00	.33
CH	.00	.33	.67	.00

FC:				
PW	.11	.33	.33	.22
FC	.12	.44	.28	.12
SW	.21	.57	.21	.00
CH	.00	.50	.50	.00

SW:				
PW	.00	.83	.00	.17
FC	.09	.64	.18	.09
SW	.50	.25	.00	.25
CH	.00	1.00	.00	.00

CH:				
PW	.25	.25	.25	.25
FC	.00	.57	.43	.00
SW	.25	.00	.25	.50
CH	.25	.25	.25	.25

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 9.03 n. s.

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(36 D.F.): 33.92 n. s.

ESTIMATED TRANSITION PROBABILITY MATRICES

ARCTIC MATE 1

V:

	V	R	C	N
V	.61	.13	.05	.19
R	.46	.11	.18	.25
C	.86	.14	.00	.00
N	.52	.26	.03	.19

R:

V	.42	.19	.12	.27
R	.22	.56	.11	.11
C	.50	.33	.00	.17
N	.50	.44	.06	.00

C:

V	.36	.27	.00	.36
R	1.00	.00	.00	.00
C	1.00	.00	.00	.00
N	.50	.00	.50	.00

N:

V	.45	.35	.00	.19
R	.50	.00	.00	.50
C	.33	.00	.33	.33
N	.71	.14	.00	.14

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 9.97 n. s.

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(36 D.F.): 61.98 n. s.

ESTIMATED TRANSITION PROBABILITY MATRICES

THULELAND CAPTAIN

PW:	PW	SW	CH	SR
PW	.00	.00	.50	.50
SW	.63	.04	.22	.11
CH	.83	.00	.00	.17
SR	.50	.50	.00	.00

SW:

PW	.00	.61	.25	.11
SW	.00	.00	.00	1.00
CH	.38	.38	.00	.25
SR	.00	.86	.14	.00

CH:

PW	.14	.57	.21	.07
SW	.67	.00	.00	.33
CH	.25	.25	.25	.25
SR	.17	.50	.17	.17

SR:

PW	.00	.50	.25	.25
SW	.69	.00	.15	.15
CH	.00	.00	.00	1.00
SR	.00	1.00	.00	.00

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 69.23 $p < .005$

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(36 D.F.): 39.29 n. s.

POSITION SEQUENCE ANALYSIS
SHIP: THULELAND
OFFICER: CAPTAIN

NUMBER OF OBSERVATIONS CONSIDERED: 135

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	PW	SW	CH	SR
PW	2.00	27.00	12.00	6.00
SW	28.00	1.00	8.00	7.00
CH	14.00	3.00	.00	6.00
SR	4.00	13.00	2.00	1.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	PW	SW	CH	SR
PW	.04	.57	.26	.13
SW	.64	.02	.18	.16
CH	.61	.13	.00	.26
SR	.20	.65	.10	.05

SECOND-ORDER TRANSITION FREQUENCY MATRICES

PW:

	PW	SW	CH	SR
PW	.00	.00	1.00	1.00
SW	17.00	1.00	6.00	3.00
CH	10.00	.00	.00	2.00
SR	3.00	3.00	.00	.00

SW:

PW	.00	17.00	7.00	3.00
SW	.00	.00	.00	1.00
CH	3.00	3.00	.00	2.00
SR	.00	6.00	1.00	.00

CH:

PW	2.00	8.00	3.00	1.00
SW	2.00	.00	.00	1.00
CH	.00	.00	.00	.00
SR	1.00	3.00	1.00	1.00

SR:

PW	.00	2.00	1.00	1.00
SW	9.00	.00	2.00	2.00
CH	.00	.00	.00	2.00
SR	.00	1.00	.00	.00

ESTIMATED TRANSITION PROBABILITY MATRICES

ARCTIC MATE 2

V:	V	R	C	N
V	.60	.12	.13	.15
R	.67	.06	.11	.17
C	.55	.09	.00	.36
N	.24	.24	.12	.41
R:				
V	.55	.27	.09	.09
R	.67	.33	.00	.00
C	.50	.50	.00	.00
N	.67	.17	.00	.17
C:				
V	.33	.22	.22	.22
R	.40	.40	.00	.20
C	.25	.25	.25	.25
N	.38	.00	.50	.13
N:				
V	.38	.31	.00	.31
R	.50	.00	.25	.25
C	.13	.25	.00	.50
N	.40	.30	.20	.10

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 11.09 n. s.

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(36 D.F.): 41.66 n. s.

ACTIVITY SEQUENCE ANALYSIS
SHIP: ARCTIC
OFFICER: MATE2

NUMBER OF OBSERVATIONS CONSIDERED: 201

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	V	R	C	N
V	52.00	18.00	11.00	17.00
R	22.00	6.00	4.00	6.00
C	9.00	5.00	.00	8.00
N	16.00	8.00	8.00	10.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	V	R	C	N
V	.53	.18	.11	.17
R	.59	.16	.11	.16
C	.39	.22	.00	.35
N	.39	.20	.20	.24

SECOND-ORDER TRANSITION FREQUENCY MATRICES

V:

	V	R	C	N
V	31.00	6.00	7.00	8.00
R	12.00	1.00	2.00	3.00
C	6.00	1.00	.00	4.00
N	4.00	4.00	2.00	7.00

R:

V	12.00	6.00	2.00	2.00
R	4.00	2.00	.00	.00
C	2.00	2.00	.00	.00
N	4.00	1.00	.00	1.00

C:

V	3.00	2.00	2.00	2.00
R	2.00	2.00	.00	1.00
C	.00	.00	.00	.00
N	3.00	.00	4.00	1.00

N:

V	6.00	5.00	.00	5.00
R	4.00	.00	2.00	2.00
C	1.00	2.00	.00	4.00
N	4.00	3.00	2.00	1.00

POSITION SEQUENCE ANALYSIS
SHIP: THULELAND
OFFICER: MATE1

NUMBER OF OBSERVATIONS CONSIDERED: 138

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	PW	SW	CH	SR
PW	1.00	30.00	11.00	9.00
SW	30.00	1.00	3.00	7.00
CH	15.00	2.00	1.00	5.00
SR	5.00	9.00	7.00	1.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	PW	SW	CH	SR
PW	.02	.60	.22	.18
SW	.71	.02	.07	.17
CH	.65	.09	.04	.22
SR	.23	.41	.32	.05

SECOND-ORDER TRANSITION FREQUENCY MATRICES

PW:

	PW	SW	CH	SR
PW	.00	1.00	.00	.00
SW	23.00	.00	2.00	4.00
CH	7.00	1.00	1.00	2.00
SR	1.00	4.00	3.00	1.00

SW:

PW	1.00	17.00	6.00	6.00
SW	.00	.00	.00	1.00
CH	1.00	.00	.00	2.00
SR	4.00	2.00	1.00	.00

CH:

PW	.00	9.00	4.00	2.00
SW	1.00	.00	1.00	.00
CH	1.00	.00	.00	.00
SR	.00	3.00	2.00	.00

SR:

PW	.00	3.00	1.00	1.00
SW	6.00	1.00	.00	2.00
CH	5.00	1.00	.00	1.00
SR	.00	.00	1.00	.00

ESTIMATED TRANSITION PROBABILITY MATRICES

THULELAND MATE 1

PW:	PW	SW	CH	SR
PW	.00	1.00	.00	.00
SW	.77	.00	.07	.13
CH	.64	.09	.09	.18
SR	.11	.44	.33	.11

SW:				
PW	.03	.57	.20	.20
SW	.00	.00	.00	1.00
CH	.33	.00	.00	.67
SR	.57	.29	.14	.00

CH:				
PW	.00	.60	.27	.13
SW	.50	.00	.50	.00
CH	1.00	.00	.00	.00
SR	.00	.60	.40	.00

SR:				
PW	.00	.60	.20	.20
SW	.67	.11	.00	.22
CH	.71	.14	.00	.14
SR	.00	.00	1.00	.00

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 77.25 $p < .005$

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(36 D.F.): 33.24 n. s.

POSITION SEQUENCE ANALYSIS
SHIP: THULELAND
OFFICER: MATE2

NUMBER OF OBSERVATIONS CONSIDERED: 60

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	PW	SW	CH	SR
PW	1.00	4.00	3.00	5.00
SW	6.00	.00	1.00	1.00
CH	3.00	1.00	4.00	10.00
SR	4.00	3.00	9.00	4.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	PW	SW	CH	SR
PW	.07	.29	.21	.36
SW	.75	.00	.13	.13
CH	.17	.06	.22	.56
SR	.21	.16	.47	.21

SECOND-ORDER TRANSITION FREQUENCY MATRICES

PW:

	PW	SW	CH	SR
PW	.00	1.00	.00	.00
SW	2.00	.00	1.00	1.00
CH	.00	.00	.00	3.00
SR	1.00	.00	2.00	2.00

SW:

PW	1.00	2.00	1.00	2.00
SW	.00	.00	.00	.00
CH	.00	.00	.00	1.00
SR	.00	1.00	.00	.00

CH:

PW	.00	.00	2.00	1.00
SW	1.00	.00	.00	.00
CH	2.00	1.00	1.00	.00
SR	3.00	2.00	3.00	2.00

SR:

PW	.00	1.00	.00	2.00
SW	3.00	.00	.00	.00
CH	1.00	.00	3.00	5.00
SR	.00	.00	4.00	.00

ESTIMATED TRANSITION PROBABILITY MATRICES

THULELAND MATE 2

PW:	PW	SW	CH	SR
PW	.00	1.00	.00	.00
SW	.50	.00	.25	.25
CH	.00	.00	.00	1.00
SR	.20	.00	.40	.40
SW:				
PW	.17	.33	.17	.33
SW	.25	.25	.25	.25
CH	.00	.00	.00	1.00
SR	.00	1.00	.00	.00
CH:				
PW	.00	.00	.67	.33
SW	1.00	.00	.00	.00
CH	.50	.25	.25	.00
SR	.30	.20	.30	.20
SR:				
PW	.00	.25	.00	.50
SW	1.00	.00	.00	.00
CH	.11	.00	.33	.56
SR	.00	.00	1.00	.00

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 23.86 $p < .005$

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY

Chi square (36 d.f.) = 36.19, n.s.

ESTIMATED TRANSITION PROBABILITY MATRICES
KIGORIAK MATE 1

V:	V	R	C	M
V	.00	.00	.00	1.00
R	.62	.00	.15	.23
C	.67	.17	.00	.17
M	.79	.00	.11	.11

R:				
V	.00	.40	.40	.20
R	.25	.25	.25	.25
C	.33	.00	.33	.33
M	.22	.11	.44	.22

C:				
V	.08	.50	.33	.08
R	.33	.00	.50	.17
C	.00	.13	.56	.25
M	.10	.10	.45	.35

M:				
V	.00	.14	.19	.67
R	.00	.00	.17	.83
C	.10	.10	.24	.57
M	.07	.10	.21	.62

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 27.39 $p < .005$

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(36 D.F.): 98.76 $p < .005$

STOP

ACTIVITY SEQUENCE ANALYSIS
SHIP: KIGORIAK
OFFICER: MATE1

NUMBER OF OBSERVATIONS CONSIDERED: 202

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	V	R	C	M
V	1.00	13.00	12.00	19.00
R	10.00	.00	6.00	9.00
C	12.00	6.00	16.00	20.00
M	21.00	6.00	21.00	29.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	V	R	C	M
V	.02	.29	.27	.42
R	.40	.00	.24	.36
C	.22	.11	.29	.36
M	.28	.08	.28	.38

SECOND-ORDER TRANSITION FREQUENCY MATRICES

V:

	V	R	C	M
V	.00	.00	.00	1.00
R	8.00	.00	2.00	3.00
C	8.00	2.00	.00	2.00
M	15.00	.00	2.00	2.00

R:

V	.00	4.00	4.00	2.00
R	.00	.00	.00	.00
C	2.00	.00	2.00	2.00
M	2.00	1.00	4.00	2.00

C:

V	1.00	6.00	4.00	1.00
R	2.00	.00	3.00	1.00
C	.00	2.00	9.00	4.00
M	2.00	2.00	9.00	7.00

M:

V	.00	3.00	4.00	14.00
R	.00	.00	1.00	5.00
C	2.00	2.00	5.00	12.00
M	2.00	3.00	6.00	18.00

ESTIMATED TRANSITION PROBABILITY MATRICES
KIGORIAK CAPTAIN

V:	V	R	C	M
V	.42	.00	.42	.17
R	.75	.00	.00	.25
C	.52	.10	.21	.17
M	.57	.10	.24	.10

R:				
V	.00	.33	.33	.33
R	.00	.00	.33	.67
C	.00	.00	.33	.67
M	.11	.46	.19	.24

C:				
V	.24	.05	.67	.05
R	.25	.13	.13	.50
C	.20	.10	.40	.30
M	.13	.13	.43	.31

M:				
V	.08	.04	.31	.58
R	.03	.06	.03	.88
C	.04	.06	.10	.79
M	.06	.15	.32	.47

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 54.65 $p < .005$

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(36 D.F.): 155.24 $p < .005$

ACTIVITY SEQUENCE ANALYSIS
SHIP: KIGORIAK
OFFICER: CAPTAIN

NUMBER OF OBSERVATIONS CONSIDERED: 384

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	V	R	C	M
V	12.00	4.00	29.00	21.00
R	6.00	3.00	3.00	37.00
C	21.00	8.00	20.00	54.00
M	26.00	34.00	52.00	53.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	V	R	C	M
V	.18	.06	.44	.32
R	.12	.06	.06	.76
C	.20	.08	.19	.52
M	.16	.21	.32	.32

SECOND-ORDER TRANSITION FREQUENCY MATRICES

V:

	V	R	C	M
V	5.00	.00	5.00	2.00
R	3.00	.00	.00	1.00
C	15.00	3.00	6.00	5.00
M	12.00	2.00	5.00	2.00

R:

V	.00	2.00	2.00	2.00
R	.00	.00	1.00	2.00
C	.00	.00	1.00	2.00
M	4.00	17.00	7.00	9.00

C:

V	5.00	1.00	14.00	1.00
R	2.00	1.00	1.00	4.00
C	4.00	2.00	8.00	6.00
M	7.00	7.00	23.00	17.00

M:

V	2.00	1.00	8.00	15.00
R	1.00	2.00	1.00	30.00
C	2.00	3.00	5.00	41.00
M	3.00	8.00	17.00	25.00

ESTIMATED TRANSITION PROBABILITY MATRICES

THULELAND MATE 2

V:	V	R	C	N
V	.55	.18	.09	.18
R	.60	.00	.07	.33
C	.73	.27	.00	.00
N	.14	.86	.00	.00
R:				
V	.15	.55	.10	.20
R	.25	.25	.25	.25
C	.67	.00	.00	.33
N	.22	.67	.11	.00
C:				
V	.10	.10	.80	.00
R	.75	.00	.25	.00
C	.25	.25	.25	.25
N	.00	.50	.50	.00
N:				
V	.50	.25	.00	.25
R	.54	.00	.08	.31
C	.00	.50	.00	.50
N	.25	.25	.25	.25

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 44.16 $p < .005$

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(36 D.F.): 44.49 n. s.

ACTIVITY SEQUENCE ANALYSIS
SHIP: THULELAND
OFFICER: MATE2

NUMBER OF OBSERVATIONS CONSIDERED: 112

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	V	R	C	N
V	11.00	15.00	11.00	7.00
R	20.00	.00	3.00	9.00
C	10.00	4.00	.00	2.00
N	4.00	13.00	2.00	.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	V	R	C	N
V	.25	.34	.25	.16
R	.63	.00	.09	.28
C	.63	.25	.00	.13
N	.22	.72	.11	.00

SECOND-ORDER TRANSITION FREQUENCY MATRICES

V:

	V	R	C	N
V	6.00	2.00	1.00	2.00
R	9.00	.00	1.00	5.00
C	8.00	3.00	.00	.00
N	1.00	6.00	.00	.00

R:

	V	R	C	N
V	3.00	11.00	2.00	4.00
R	.00	.00	.00	.00
C	2.00	.00	.00	1.00
N	2.00	6.00	1.00	.00

C:

	V	R	C	N
V	1.00	1.00	8.00	.00
R	3.00	.00	1.00	.00
C	.00	.00	.00	.00
N	.00	1.00	1.00	.00

N:

	V	R	C	N
V	2.00	1.00	.00	1.00
R	7.00	.00	1.00	4.00
C	.00	1.00	.00	1.00
N	.00	.00	.00	.00

ESTIMATED TRANSITION PROBABILITY MATRICES

THULELAND MATE 1

V:	V	R	C	N
V	.29	.18	.18	.35
R	.70	.00	.00	.30
C	.83	.17	.00	.00
N	.73	.12	.12	.04
R:				
V	.15	.00	.46	.38
R	.25	.25	.25	.25
C	1.00	.00	.00	.00
N	.50	.25	.25	.00
C:				
V	.20	.13	.53	.10
R	.60	.00	.40	.00
C	.25	.25	.25	.25
N	1.00	.00	.00	.00
N:				
V	.17	.13	.22	.48
R	.75	.00	.00	.25
C	.75	.00	.00	.25
N	1.00	.00	1.00	.00

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 65.17 $p < .005$

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(36 D.F.): 39.96 n. s.

ACTIVITY SEQUENCE ANALYSIS
SHIP: THULELAND
OFFICER: MATE1

NUMBER OF OBSERVATIONS CONSIDERED: 172

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	V	R	C	N
V	17.00	10.00	30.00	26.00
R	13.00	.00	2.00	4.00
C	30.00	5.00	.00	1.00
N	23.00	4.00	4.00	1.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	V	R	C	N
V	.20	.12	.36	.31
R	.68	.00	.11	.21
C	.83	.14	.00	.03
N	.72	.13	.13	.03

SECOND-ORDER TRANSITION FREQUENCY MATRICES

V:

	V	R	C	N
V	5.00	3.00	3.00	6.00
R	7.00	.00	.00	3.00
C	25.00	5.00	.00	.00
N	19.00	3.00	3.00	1.00

R:

V	2.00	.00	6.00	5.00
R	.00	.00	.00	.00
C	2.00	.00	.00	.00
N	2.00	1.00	1.00	.00

C:

V	6.00	4.00	16.00	3.00
R	3.00	.00	2.00	.00
C	.00	.00	.00	.00
N	1.00	.00	.00	.00

N:

V	4.00	3.00	5.00	11.00
R	3.00	.00	.00	1.00
C	3.00	.00	.00	1.00
N	1.00	.00	1.00	.00

ESTIMATED TRANSITION PROBABILITY MATRICES

THULELAND CAPTAIN

V:	V	R	C	N
V	.30	.10	.17	.43
R	.67	.00	.17	.17
C	.84	.08	.04	.04
N	.67	.10	.14	.05
R:				
V	.25	.00	.50	.25
R	.25	.25	.25	.25
C	1.00	.00	.00	.00
N	.00	.33	.67	.00
C:				
V	.35	.04	.54	.08
R	.67	.00	.00	.33
C	1.00	.00	.00	.00
N	1.00	.00	.00	.00
N:				
V	.53	.12	.12	.24
R	.67	.00	.00	.33
C	.60	.20	.00	.20
N	1.00	.00	.00	.00

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 29.77 $p < .005$

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(36 D.F.): 33.71 n. s.

ACTIVITY SEQUENCE ANALYSIS
SHIP: THULELAND
OFFICER: CAPTAIN

NUMBER OF OBSERVATIONS CONSIDERED: 154

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	V	R	C	N
V	30.00	6.00	25.00	21.00
R	8.00	.00	1.00	3.00
C	26.00	3.00	1.00	2.00
N	17.00	3.00	5.00	1.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	V	R	C	N
V	.37	.07	.31	.26
R	.67	.00	.08	.25
C	.81	.09	.03	.06
N	.63	.11	.19	.04

SECOND-ORDER TRANSITION FREQUENCY MATRICES

V:

	V	R	C	N
V	9.00	3.00	5.00	13.00
R	4.00	.00	1.00	1.00
C	21.00	2.00	1.00	1.00
N	14.00	2.00	3.00	1.00

R:

V	2.00	.00	4.00	2.00
R	.00	.00	.00	.00
C	1.00	.00	.00	.00
N	.00	1.00	2.00	.00

C:

V	9.00	1.00	14.00	2.00
R	2.00	.00	.00	1.00
C	1.00	.00	.00	.00
N	2.00	.00	.00	.00

N:

V	9.00	2.00	2.00	4.00
R	2.00	.00	.00	1.00
C	3.00	1.00	.00	1.00
N	1.00	.00	.00	.00

ACTIVITY SEQUENCE ANALYSIS
SHIP: KIGORIAK
OFFICER: MATE2

NUMBER OF OBSERVATIONS CONSIDERED: 209

FIRST-ORDER TRANSITION FREQUENCY MATRIX

	V	R	C	M
V	3.00	21.00	17.00	8.00
R	22.00	1.00	14.00	5.00
C	16.00	12.00	9.00	18.00
M	8.00	10.00	14.00	30.00

ESTIMATED TRANSITION PROBABILITY MATRIX

	V	R	C	M
V	.06	.43	.35	.16
R	.51	.02	.33	.12
C	.30	.22	.17	.33
M	.13	.16	.23	.49

SECOND-ORDER TRANSITION FREQUENCY MATRICES

V:

	V	R	C	M
V	.00	.00	3.00	.00
R	16.00	.00	4.00	.00
C	12.00	3.00	1.00	1.00
M	3.00	2.00	1.00	2.00

R:

V	.00	12.00	4.00	6.00
R	.00	.00	.00	1.00
C	4.00	5.00	1.00	4.00
M	1.00	.00	2.00	2.00

C:

V	3.00	5.00	8.00	.00
R	3.00	.00	8.00	1.00
C	.00	1.00	4.00	4.00
M	1.00	5.00	7.00	5.00

M:

V	.00	4.00	2.00	2.00
R	3.00	1.00	2.00	4.00
C	.00	3.00	3.00	8.00
M	3.00	2.00	4.00	21.00

ESTIMATED TRANSITION PROBABILITY MATRICES

KIGORIAK MATE 2

V:	V	R	C	M
V	.00	.00	1.00	.00
R	.76	.00	.19	.00
C	.71	.18	.06	.06
M	.38	.25	.13	.25

R:				
V	.00	.55	.18	.27
R	.00	.00	.00	1.00
C	.29	.36	.07	.29
M	.20	.00	.40	.40

C:				
V	.19	.31	.50	.00
R	.25	.00	.67	.08
C	.00	.11	.44	.44
M	.06	.28	.39	.28

M:				
V	.00	.50	.25	.25
R	.30	.10	.20	.40
C	.00	.21	.21	.57
M	.10	.07	.13	.70

TEST FOR ZERO- VERSUS FIRST-ORDER DEPENDENCY

CHI-SQUARE STATISTIC(9 D.F.): 63.58 $p < .005$

TEST FOR FIRST- VERSUS SECOND-ORDER DEPENDENCY

Chi square (36 d. f.) = 101.56. $p < .005$